MECHANICAL AND MORPHOLOGICAL PROPERTIES OF POLYPROPYLENE / NATURAL RUBBER BLENDING WITH ADDITIVES

ANUAR BIN JUSUH

SESSION 2004/2005

DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF MALAYA

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BY

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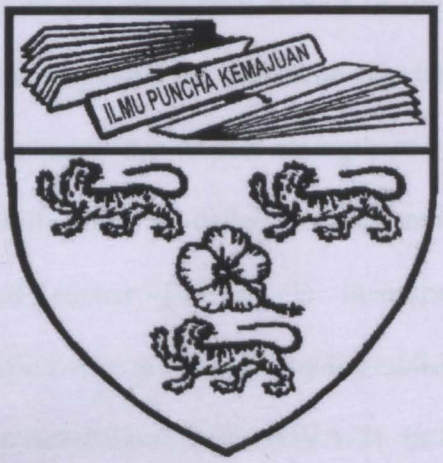

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ABSTRACT

One of the most successful methods developed for modifying and enhancing polymer properties is by polymer blending. This thesis project will focus on study of mechanical and morphology properties polypropylene (PP)/natural rubber (NR) with additive to produce a new properties polypropylene. Blends of polypropylene (PP) with elastomer are developed with the objective to overcome the inherent brittleness of PP at low temperatures and to enhance the impact strength at room temperature. The polymer blends of PP/NR will form so-called a thermoplastic natural rubber (TPNR). Thermoplastic natural rubber (TPNR) is incompatible polymer pair and the technological compatibilization was sought by the addition dicumyl peroxide (DCP) and co-agent is N, N phenylenebismaleimide (HVA-2). In this study, the DCP and HVA-2 was also shown to be an effective compatibilizer by reducing the interfacial tension and improving adhesion between immiscible polymers thus increasing the compatibility of the blend. The blends were prepared in an extruder laboratory with various compositions. After mixing and palletizing, the samples were then injection molded and test for mechanical properties. This was including testing on tensile test, flexural test, and impact test. Differential Scanning Calorimeter (DSC) and Scanning Electron Microscope (SEM) also used to evaluate the morphology of the PP/NR blends. From the results in this thesis, an increase in impact strength and elongation at break but a decrease of tensile strength, yield strength, break strength and flexural modulus were observed with increasing natural rubber (NR)

ABSTRAK

Salah satu teknik yang paling berjaya untuk mengubahsuai dan meningkatkan sifat-sifat polimer adalah dengan pengadunan polymer. Dalam kajian tesis yang dijalankan ini, ianya difokuskan untuk mengkaji sifat mekanikal dan morfologi polypropylene (PP)/natural rubber (NR) dengan campuran bahan tambahan untuk menghasilkan sifat baru polypropylene. Adunan PP dengan elastomer dikembangkan dengan objektif untuk mengatasi masalah sifat kerapuhan PP pada suhu rendah dan untuk mempertingkatkan kelemahan hentaman pada suhu bilik. Adunan polimer daripada PP/NR juga dipanggil sebagai thermoplastic natural rubber (TPNR). Thermoplastic natural rubber (TPNR) ialah gabungan polimer yang tidak serasi, teknologi penserasian telah dicari dengan cara penambahan dicumyl peroxide (DCP) dan pembantu DCP iaitu N,N phenylenebismaleimide (HVA-2). Dalam kajian ini, DCP dan HVA-2 telah memberi kesan penserasian dimana ianya mengurangkan kekuatan antara muka diantara polimer yang tidak serasi, seterusnya meningkatkan penserasian dalam adunan. Adunan disediakan didalam makmal pengadun dengan pelbagai komposisi. Setelah proses pencampuran dan pembutiran, butiran adunan disuntik ke dalam acuan untuk penghasilan sampel dan seterusnya diuji sifat mekanikalnya.. Kajian sifat mekanikal yang dijalankan ialah ujian tegangan, ujian lenturan dan ujian hentaman. Differential Scanning Calorimeter (DSC) dan Scanning Electron Microscope (SEM) juga telah dilakukan untuk menilai morfologi adunan PP/NR. Daripada keputusan kajian yang dilakukan ini, adunan telah meningkatkan kekuatan hentaman dan pemanjangan pada takat putus tetapi terdapat penurunan dalam kekuatan tegangan, kekuatan alah, kekuatan

patah dan modulus lenturan dimana dapat diperhatikan dengan peningkatan campuran getah asli.

ACKNOWLEDGEMENT

In the name of Allah SWT, the most gracious, the most merciful, all praise to almighty Allah SWT the sustainer of the world, blessing and peace is upon his messenger Muhammad SAW for giving me the strength and spirit to have this project completed successfully.

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Regards,

Anuar Bin Jusoh,

Engineering of Material Student,

University of Malaya.

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CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1 Introduction

The concept of combining together two or more different polymers to obtain a new material system with the desirable features of its constituents is not new. Over the years numerous system based on the chemical combination of different monomers have been developed. Over the last decade, the interest in polymer blend systems as a way to meet new market application with minimum development cost has increased rapidly.

A polymer blend is a physical mixture of two, or sometimes more, different polymers. The term is usually used to refer to mixtures in which the polymers are of different chemical types. Sometimes, however, the term refers merely to mixtures of polymers of the same types but different grades, e.g. of different molecular weight. Normally, blends are simple physical mixtures, but in practice the blending process often gives rise to some covalent chemical bonding between the different types of polymer molecule.

The emergence of thermoplastics elastomers (TPEs) is one of the important developments in the field of polymer science. TPEs are a new class of materials which combine the properties of vulcanized rubber with the ease of process ability of thermoplastics. Blends of natural rubber and polypropylene form a new class of TPEs of

much important. Natural rubber vulcanized characterized by good elastic properties, good resilience and damping behavior but poor chemical resistance and process ability. On the other hand, polypropylene exhibit superior processing characteristic, however, it is extremely brittle at low temperatures. TPEs from NR/PP blends are expected to exhibit good process ability, impact strength, good flexibility and rubber nature (R. Asaletha et.al, 1999).

The compatibility of the polymer component is crucial in determining the blend properties that have significant influence on strength properties. It is the limited compatibility of most polymer pairs that has until recently restricted the commercial use. To improve the mechanical properties of the polymer blends, compatibility between the polymers is an important issue to study. To overcome the incompatibility and produce a compatible blend, the mixing of the two polymers during blending require an agent that can induce interactions within the phases, between phases or at the interface. In this thesis, the technological compatibilization was sought by the addition DCP and co-agent (HVA-2).

The properties of the PP/NR specimens is depend on how the blends are prepared. The microstructure and properties of these blends have been analyzed in this laboratory recently. In the present communication, I report on the morphological and mechanical properties of polypropylene (PP)/ natural rubber (NR) with additives.

1.2 Objective of Project

The main objective of this thesis project is to improve the impact strength of polypropylene by blending with natural rubber (NR) and using of additives. The studies on mechanical and morphological properties of the blend with several difference compositions will be performed for this purpose.

1.3 Scope of Work

The scopes of work for this project are as follows:-

- Study on blending process, resins and the equipment used for blending such as extruder and injection molding.
- Perform the mechanical tests to determine the samples mechanical properties
- Observe the morphologies of polymer blends by using Differential Scanning Calorimeter (DCS) and Scanning Electron Microscope (SEM).
- Analyze the result and make discussion on polypropylene (PP)/natural rubber (NR) blends with additives.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review

Polymer and, in particular, elastomers have evolved into mature products over the last thirty years, with well-established application, most of which around the consumer. Despite this materials being mature, and market applications well established, this is by no means a stagnant industry or subject. Driven by fierce competition, product quality improvement, and new application in such market segments as health care, automotive parts, construction and building materials, mechanical goods, and enormous range of composites with specialty or niche-type application and manufactures of elastomers, plastic blends, and polymeric alloying materials continue to strive for new products and variation of feedstock polymers. This volume provides a compendium of some of the latest technological advancements in product applications, new elastomers, blends, alloys, and functionalized materials (Nicholas P.Cheremisinoff, 1997).

Polymer blends have now come to the front as such a major effort. Their current and potential technological importance is remarkable and they are everywhere presence in consumer products is testimony to their commercial importance. The combination of two or more polymer through alloying or blending however represents an inexpensive route to products differentiation for suppliers. Existing equipment may be utilized and the properties and chemical behavior of the constituents are generally well understood. For the processor and the end user, alloying and blending technology permits tailoring of

a polymer compound to their specific applications requirements, often at lower cost than the current material and over a shorter developmental period (Melvyn, A. kohudic, 1998). Alloy and blend development is typically market driven and requires an ongoing dialogue between supplier and customer to enable commercial success (Utracki, LA, 1998).

The emergence of thermoplastic elastomers (TPEs) is one of the important developments in the field of polymer science and technology in recent year. TPEs are a new class of materials which combine the properties of vulcanized rubbers with the ease of process ability of thermoplastics. TPEs from rubber-plastic blends become important because they combine the superior processability of thermoplastics and the very good mechanical properties of the elastomer. The morphology and properties of TPEs have been extensively reported. Morphology and mechanical properties of NR/PS blends have been analyzed with special reference to the effect of blend ratio, processing conditions and vulcanizing systems (R. Asaletha et al, 1999).

Polymer blending is an effective way to achieve desirable combination of properties that are often absent in single component polymers. However, simply mixing two or more polymers together will not ensure the blend with desirable properties because of the incompatibility. TPEs are immiscible and incompatible and exhibit poor properties. This problem can be alleviated by the proper addition of suitable

compatibilizers, which may be a block copolymer or graft copolymer (Nicholas P. Cheremisinoff, 1997).

2.2 Introduction of Polymers and Plastics

Plastic is one of the application groups of polymers. Plastic have been growing very rapidly and have replaced ceramics, glasses, rubber, wood and paper in various industries such as packaging, furniture, consumer products, transportation, building and construction, mechanical parts, electrical and electronics components, agriculture etc. the advantages of plastics are cost effective lightness, ease of processing, fire retarding, colour fastness, resilience, resistance to corrosion, heat and electricity.

The term plastic refers to a solid material the primary ingredient of which is an organic polymer of high molecular weight; it may also contain additives such as fillers, plasticizers, flame retardants, and the like.

Polymers are materials which consist of very long chain-like molecules (typical molecular weights can be in the region of 300,000). These synthetic large molecules are made by joining together thousands of small molecular units known as monomers. The process of joining the monomers together is called polymerization and the number of these units in the long molecule is known as the degree of polymerization. The names of many polymers consist of the name monomer with the suffix "poly-". For example, the

polymers polypropylene and polystyrene are produced from propylene and styrene respectively.

The words polymers and plastic are often taken as synonymous but in fact there is a distinction. The polymer is the pure material which results from the process of polymerization and is usually taken as the family name for materials which have long chain-like molecules and this includes rubber. Pure polymers are seldom used their own and it is when additives are present that the term plastic is applied. Polymers contain additives for a number of reasons. In some cases impurities are present as a result of the polymerization process and it may be uneconomic to remove these to get the pure polymers. In other cases additives such as stabilizers, lubricants, filler, pigments, etc. are added to enhance the properties of the material. By the tradition the term plastic excludes rubber.

2.3 Classification of Polymers

There are numerous classifications for polymers. Once classification scheme is according to the mechanical response at elevated temperature, in which polymeric materials are classified as thermoplastics and thermosetting polymers.

2.3.1 Thermoplastic and Thermosetting Polymer

Thermoplasts or thermoplastic polymers and thermosets or thermosetting polymers are the two subdivisions. Thermoplastic polymers soften when heated and harden when cooled, processes that are totally reversible and maybe repeated. These materials are normally fabricated by the simultaneous application of heat and pressure. On a molecular, as the temperature is raised, secondary bonding forces are diminished by increased molecular motion so that the relative movement of adjacent chains is facilitated when a stress is applied. Irreversible degradation results when the temperature of a molten thermoplastic polymer is raised to the point at which molecular vibrations become violent enough to break the primary covalent bonds. In addition, thermoplastic polymers become are relatively soft and ductile. Most linear polymers and those having some branched structures with flexible chains are thermoplastic.

Thermosetting polymers become permanently hard when heat is applied and do not soften upon subsequent heating. During the initial heat treatment, covalent crosslinks are formed between adjacent molecular chains; these bonds anchor the chains together to resist the vibrational and rotation chain motions at high temperatures. Crosslinking is

usually extensive, in that 10 to 50% of the chain mer units are crosslink bonds and polymer degradation. Thermoset polymers are generally harder, stronger, and more brittle than thermoplastics, and have better dimensional stability. Most of the crosslinked and network polymers, which include vulcanized rubbers, epoxies, and phenolic and some polyester resins, are thermosetting (Callister, W.D., 1999)

2.4 Properties of Plastic and Polymers

The bonding properties and chemical versatility of carbon account for the great number of plastics. Although carbon is the backbone of polymer chains, other elements are included, to varying degrees, in the chemical structures of plastics. These include hydrogen, oxygen, nitrogen, chlorine, fluorine, and occasionally other elements, such as sulphur and silicon.

While progress in polymer technology makes it increasingly difficult to make general statements about these material s, the following properties are characteristic of most plastics:

- Low strength – for the familiar plastic, about one-sixth the strength of structural steel.
- Low stiffness (technically, modulus of elasticity) – less than one-tenth that of metals, except for reinforced plastics.
- A tendency to creep. That is, to increase in length under a tensile stress.

- Low hardness (except formaldehyde plastics).
- Low density, usually an advantage, the density of most plastics being close to that of water.
- Brittleness at low temperatures and loss of strength and hardness at moderately elevate temperatures (Thermal expansion of plastics is about ten times that of metals).
- Flammability, although many plastics do not burn.
- Outstanding electrical characteristics, such as electrical resistance
- Degradation of some plastics by environmental agencies such as ultraviolet radiation, although most plastics are highly resistant to chemical attack.

2.5 Introduction of Polymer Blends

Polymer blends are physical mixtures of at least two structurally different polymers, which adhere together with no covalent bonding between them. Polymer blends are also called multiphase polymer or polymer alloys. Each constituent can be a polymer or a copolymer, with a linear, branched or cross-linked structure. When one of the mixed polymers is the minor component, it can be considered simply as an additive. In the search for new polymeric materials, the blending of polymers is a promising method for obtaining desirable properties using already known polymers. Such system should provide a relatively simple solution to complex economic and technological problems. Polymer blends are now of great scientific and industrial interest. Several blends of commercial importance already exist.

The commercial polymer blends can be plastic-plastic, plastic-rubber or rubber-rubber (Utracki, L.A., 1998). Their application leads to a reduction in the amount of the more expensive material necessary and to an improvement in the properties. In this way high performance material can be developed from synergistically interacting polymers (Prichard, G., 1998). Another possible application of polymer blending is recycling industrial plastics waste.

There are different ways to mix polymers, melt blending, solution blending and latex or dispersion blending. Melt blending using an extruder is the predominate method used to prepare blends. Injection molding is also used to mix melt blending. Polymer

component, which make up the blends, are generally selected to complement each other in one or more of the following properties such a cost, processability, mechanical properties, chemical resistance and thermal performance. The more expensive polymer is combined with the less expensive product to provide adequate performance at a significant reduced price. Very often crystalline and amorphous polymers are blended to achieve a specific property range. Crystalline polymers have excellent chemical, good mechanical properties and low viscosity whereas amorphous polymers provide good dimensionality stability and excellent impact strength (Nielsen, L.E., 1994).

2.6 Compatible of Polymer Blends

Polymers of various homologous series are, as a rule, incompatible. Their compatibility is usually observed in a very limited region of compositions. In those cases when polymers are compatible and form single-phase solution, the change of their physical state (say, temperature) may be accompanied by the precipitation of one of the polymers as an individual phase. Owing to the high viscosity of the system it may prove to be in the metastable state.

The compatibility of the polymer components is crucial in determining the blend properties, most importantly the strength properties. It is the limited compatibility of most polymer pairs that has until recently restricted the commercial use of blends. At one extreme, if the polymers are so compatible that they are completely miscible, forming a singe-phase blend, then the properties may be related to blend composition in

a simple linear manner. At the opposite extreme, when the two polymers are so completely incompatible that there is no interfacial adhesion between the two phases.

2.7 Polymeric Materials for Blends

Materials used in this thesis project are polypropylene, natural rubber and additives of blends. The description of each material is as below:-

2.7.1 Polypropylene (PP)

Polypropylene is an extremely versatile plastic and is available in many grades. It has the lowest density of a thermoplastic (in the order of 900 kg/m3) and this combined with strength, stiffness and excellent fatigue and chemical resistance make it attractive in many situations. These include crates, small machine parts, car component, cabinet for television etc. The repeating unit for polypropylene is represented in figure 2.1.

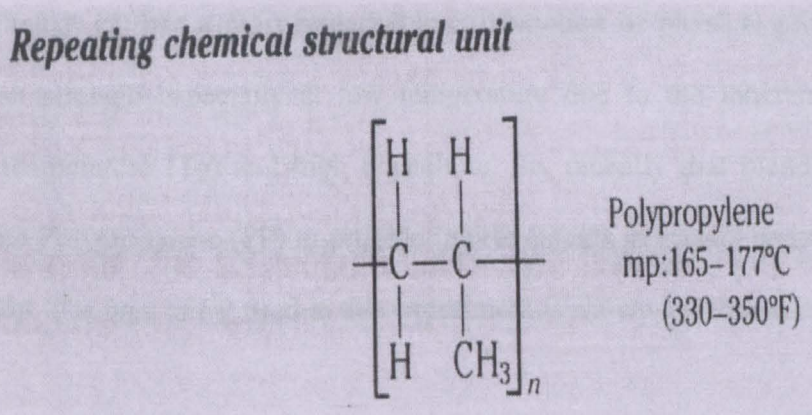


Figure 2.1: Repeating unit for polypropylene

The mechanical properties of PP are largely due to its crystalline, because of the comparatively high melting temperature, the crystalline phase retains mechanical strength up to rather high temperature. On the low temperature side the usefulness of PP is limited by its embrittlement at the glass transition temperature.

Like almost all plastic materials, PP is tough under certain conditions and brittle under others; any fracture accompanied by a large irreversible deformation is define as tough, otherwise as brittle. Brittle plastics break at their maximum stress with small elongation in tensile test; tough plastic pass through a maximum stress (yield point) before fracture occurs at a stress below the maximum. If the brittle strength exceeds the yield strength tough fracture will occur, otherwise brittle fracture. PP will essentially behave as a brittle material below its glass transition temperature and as a tough one above.

Although PP has a most remarkable combination of physical properties; it has poor impact strength especially at low temperature due to the inherently high glass transition temperature (Tg) and high crystalline. So, recently that blending of various rubbers with Polypropylene (PP) to provide improvements in impact resistance has been widely study. The type of PP used in this experiment is shown in table 2.1:

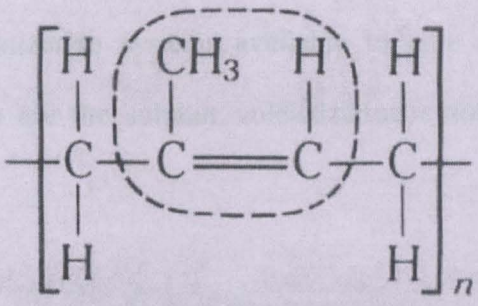
Table 2.1: Grade and relevant properties of PP used

Grade	Glass Transition Temperature °C	Melting Temperature °C
PP Copolymer SM 546-T32535	-5 to -20	165-177

2.7.2 Natural Rubber

Natural rubber is obtained from the latex from the tree Hevea Brassiliensis. The coagulum obtained by treatment of the latex with acid followed by washing and drying, contains high percentage of hydrocarbon, mixed with proteins, resins and other constituents. The typically chemical any ayes being:-hydrocarbon 94.5%, action soluble 2.8%, nitrogen 0.4% and ash 0.2%.

Natural rubber (NR) essentially consists of 1, 4 polyisoprene with average molecular weight of the order of 200 000 to 300 000. The repeating unit for natural rubber is represented in figure 2.2.



cis-1,4 Polyisoprene

Repeating structural unit for natural rubber

Figure 2.2: Repeating unit for natural rubber

Natural rubber can be achieving properties suitable for structural purposes most rubbers have to be vulcanized, i.e., the long molecules of the rubber have to be cross-linked. The cross-linking agent in vulcanization is commonly sulphur, peroxide and the stiffness and strength increase with the number of crosslink's. The type of natural rubber used in this experiment is shown in table 2.2:

Table 2.2: Grade and relevant properties of NR used

Grade	Glass Transition Temperature °C	Melting Temperature °C
SMRCV 60	-73	28

2.7.3 Additives of Blends

There are various vulcanization systems available to cure natural rubber. The two commonly used systems are the sulphur vulcanization systems and peroxide curing systems.

In this thesis project, we used peroxide curing systems to cure natural rubber. The peroxide system that used in this project is dicumyl peroxide and N.N-m-phenylenebismaleimide (HVA-2) as co-agents.

- **Dicumyl Peroxide (DCP)**

Organic peroxide can be used to crosslink natural rubber and the most commonly used peroxide is dicumyl peroxide. Natural rubber vulcanisate cured with dicumyl peroxide possesses thermally stable networks which are attributed to the stability of the carbon-carbon crosslink's. Furthermore the vulcanisate has good resistance to oxidative ageing and reversion.

Formula dicumyl peroxide: - $[C_6 H_5 C (CH_3)_2O]_2$

- **N.N-m-phenylenebismaleimide (HVA-2)**

Co agents, such as N, N – m- phenylenebismaleimide (HVA-2), are sometimes added in peroxide formulation to increase the efficiency of cross linking.

CHAPTER 3

METHODOLOGY

CHAPTER 3

METHODOLOGY

3.1 Materials Preparation

Materials that are used in this thesis project are:

- Polypropylene

Figure 3.1: Granular polypropylene copolymer

- Natural Rubber

Figure 3.2: Granular SMRCV 60

- Additives
    - Dicumyl Peroxide (DCP)
    - N.N-m-phenylenebismaleimide (HVA-2)

3.2 Preparation of Blends

In this study, the materials, that are used contains the polypropylene (PP) with the grade of granular polypropylene copolymer SM 546-T32535 and the natural rubber (NR) used was viscosity stabilize grade of Standard Malaysian Rubber (SMRCV 60) obtained by Rubber Research Institute of Malaysia. For this blending, the additive DCP and HVA-2 was used a compatibizers of the process.

Polypropylene (PP), natural rubbers (NR), dicumyl peroxide (DCP) and N.N-m-phenylenebismaleimide (HVA-2) were weighted and mixed manually according to various compositions shown in table 3.1 before being extruded.

Table 3.1: Various composition of PP/NR blend (TPNR)

	Composition (%)				
Batch	1	2	3	4	5
Polypropylene (PP)	100	80	70	50	30
NR (SMR CV 60)	0	20	30	50	70
Dicumyl Peroxide	0	0.5	0.5	0.5	0.5
HVA-2	0	3	3	3	3

The sequences of preparing the samples are simplified in the flow charts as below:

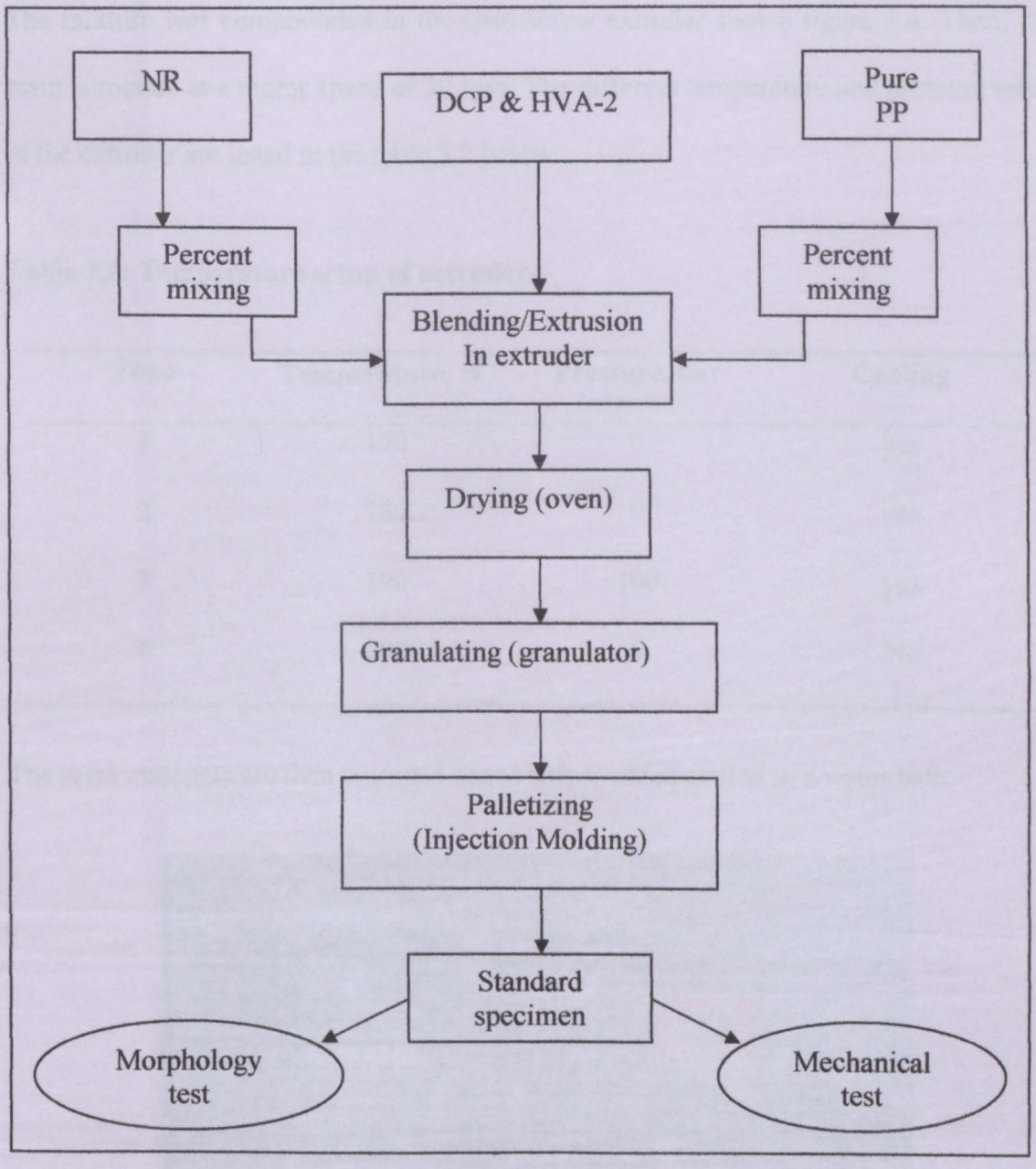


Figure 3.3: Flow chart for sample preparation

3.3 Preparation of Specimens

3.3.1 Extrusion Process

The mixture was compounded in the twin screw extruder shown figure 3.4. Then, the resin is rotated at a motor speed of 30 rpm. The different temperature and pressure setup in the extruder are listed in the table 3.2 below:

Table 3.2: Temperature setup of extruder

Zone	Temperature, °C	Pressure, bar	Cooling
1	170	0	yes
2	180	0	yes
3	190	100	yes
4	200	0	No

The resin materials are then extruded out as strips, which cooled in a water bath.

Figure 3.4: (Haake Rheocard 9000) Twin Extruder Machine

3.3.2 Oven Process

Oven as shown in figure 3.5 was used to heat the strip to get rid of moisture. This would ensure no bubble is being trapped by injection molding at the later stage. The wet strips were dried for two hours at a temperature 70°C in the oven before being granulated. This is necessary to prevent the existence of air bubbles and pores during the injection molding process. The existence of pores in test samples will affect the mechanical properties of the test samples and must be prevented.

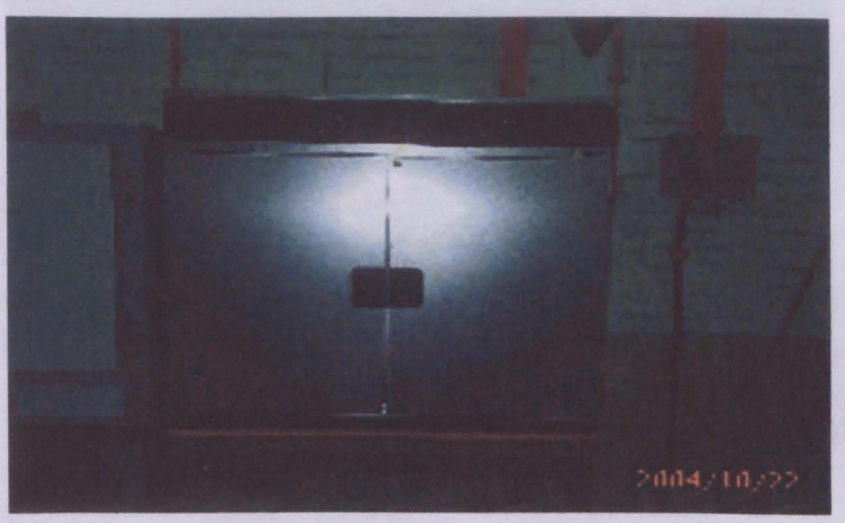


Figure 3.5: Oven

3.3.3 Granulation Process

After the dried in the oven, the strips then granulated into pellets using the granulator as shown in figure 3.6. The granulator is used to change the shape of the samples produced in extrusion process (rod form) into the granular form. This is essential in order to facilitate to help the injection process.

Figure 3.6: Rapid Granulator

3.3.4 Injection Molding Process

The granulated PP/NR blend is then injected using injection molding machine as shown in figure 3.7 to produce the PP/NR samples. Temperature settings are shown in the table 3.3 below:

Table 3.3: Temperature and pressure setup was used in injection molding process

Zone	Temp,°C	Pressure, bar
1	175	70
2	180	70
3	190	60
4	200	60

Two samples will be produced in one cycle. The test samples are for tensile test and Izod impact test.

Figure 3.7: BOY–50M Injection Molding Machine

3.3.5 Samples PP/NR Blends

Samples of PP/NR blends are shown in this figure 3.8 below:

Figure 3.8: Samples PP/NR blends

3.4 Morphological and Mechanical Testing

3.4.1 Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry is a technique use to study what happen to polymers when they are heated. It can be used to study what we call the thermal transitions of a polymer where the changes take place in a polymer when heated or to find the melting point of polymer. The melting of a crystalline polymer is one example and the glass transition is also a thermal transition.

The model used is DSC 821^e MODULE (figure 3.9) and it is used to measure the thermal properties of the blends. The calorimetry is operated under nitrogen flow of 20 cm^3 min^{-1}. The temperature is calibrated by the mp of ultra-pure materials: stearic acid, indium, tin and lead under different heating rates, corrections being made for thermal lag in the specimens.

Figure 3.9: Differential Scanning Calorimetry (DSC)

Procedures

1) We heat our polymer in a device as shown in figure 3.10:

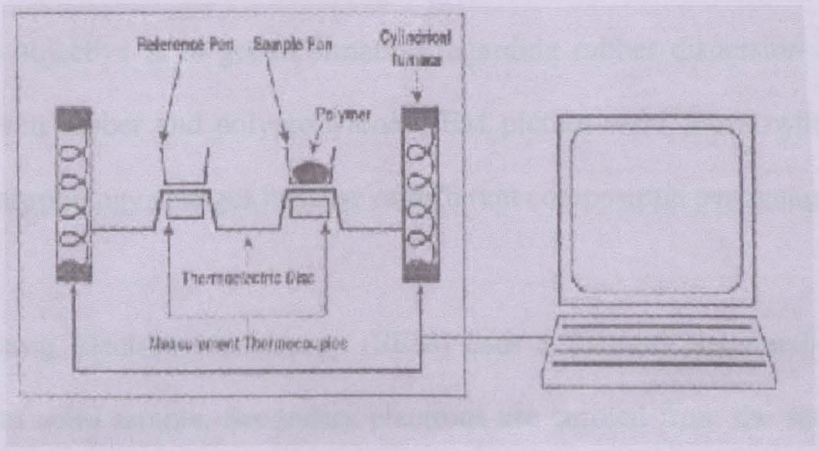


Figure 3.10: Diagram of DSC test device

2) In the most popular DSC design, two pans sit on a pair of identically positioned platforms connected to a furnace by a common heat flow path.

3) In one pan, we put the polymer sample.

4) The other one is the reference pan. Leave it empty.

5) Then tell the nifty computer to turn on the furnaces.

6) So, the computer turns on the furnace, and tells it to heat the two pans at a specific rate, usually something like 10 °C per minute.

7) The computer makes absolutely sure that the heating rate stays exactly the same throughout the experiment. But more importantly, it makes sure that the two separate pans heat at the same rate as each other.

3.4.2 Scanning Electron Microscopy (SEM)

A scanning electron microscope (SEM), model Philips XL40 (figure 3.11) was used to examine the extent of phase separation in the blends by examination of their fracture surface. The objective is to get information regarding rubber dispersion and bonding quality between rubber and polypropylene. SEM picture were shows whether the co-continuous morphology changes because of different composition percentage.

Scanning Electron Microscopy (SEM) uses a focused electron beam to scan small areas of solid sample. Secondary electrons are emitted from the sample and are collected to create an area map of the secondary emissions. Since the intensity of secondary emission is very dependent on local morphology, the area map is a magnified image of the sample. Backscattered electrons (BSE) and characteristic X-rays are generated by the scanning beam and many instruments can utilize these signals for compositional analysis of microscopically small portions of the sample.

Figure 3.11: Scanning Electron Microscopy (SEM)

Procedures

[1] This operation is required to prepare specimen morphology from different batch of polymer blends.

[2] Specimens need to be coated with gold plate under vacuum condition; to enable the specimen to be conductive in order to run the machine.

[3] Specimen under microscope is focused and analyze before picture is shot as evidence.

[4] Specimen need to be clean with soap or detergent, and then dried before insert into SEM machine.

All picture of SEM were shown in Appendix A

3.4.3 Tensile Test

Tensile properties were measured on an Instron Universal Testing Machine Series IX interfaced to a computer as shown in figure 3.12. Tensile test provide a means to characterize the mechanical properties of a polymer in terms of modulus, strength and elongation to failure. Tensile testing is the standard methods for measuring fracture resistance and it is the simplest and most easily analyzed.

Figure 3.12: Instron Testing Machine (Tensile)

The dimensions for the tensile test specimen is shown in figure 3.13 and specified in standard ASTM D 638 from Type M-1 specimen, where having overall width of 20mm and an overall length of 215 mm. The dimensions are also shown in table 3.4.

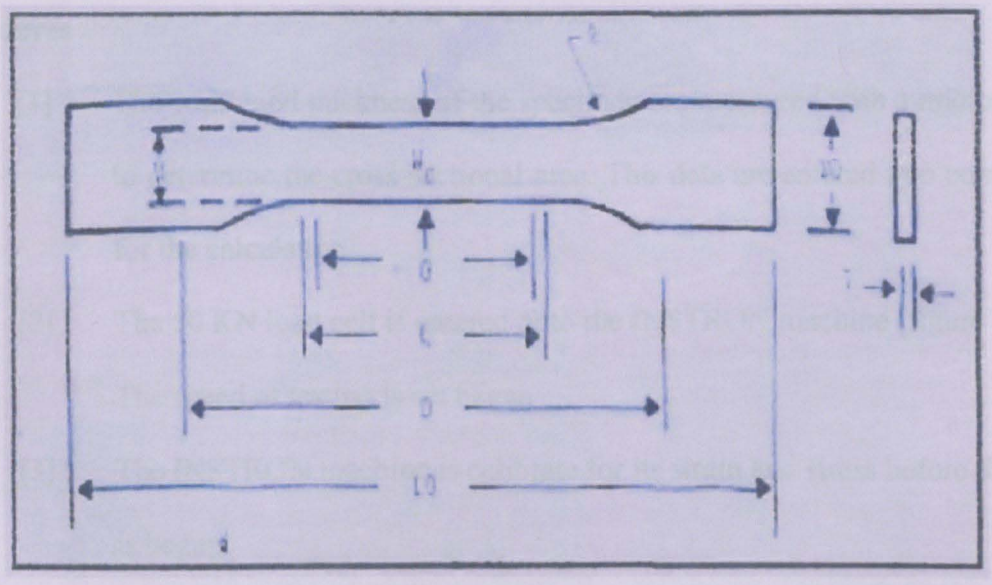


Figure 3.13: Dimension of the tensile test specimen

Table 3.4: Specimen dimension for tensile test

Dimensions	Type M-I (mm)
W-width of narrow section	10
L-length of narrow section	60
WO-width of overall, min	20
Lo-length overall, min	150
G-gage length	50
D-distance between grips	115
R-radius of fillet	60

Procedures

[1] The width and thickness of the specimen are measured with a micrometer to determine the cross-sectional-area. This data are entered into computer for the calculation.

[2] The 50 KN load cell is entered onto the INSTRON machine (figure 3.12). The speed of testing is set begun

[3] The INSTRON machine is calibrate for its strain and stress before the test is begun

[4] The specimen is placed on the grip and the long axis of the specimen and grips is aligned carefully with an imaginary line joining the points of attachment of the grip to the specimen during the test.

[5] The grips are tightened evenly and firmly to prevent slippage of the specimen during the test.

[6] The extensometer is attached to the specimen.

[7] The test is then started. The data and the necessary calculation will be done by the computer.

All data then recorded and printed as shown in Appendix B.

3.4.4 Flexural Test

The Flexural Tester Machine (figure 3.14) is used for three point flexural test. The specimens is a simple rectangular shaped beam that is placed over 2 rests or supports and then loaded in the middle of the beam between 2 supports.

Figure 3.14: Flexural Tester Machine (INSTRON)

The dimension for the flexural test (bending test) is shown on table 3.5 below and follows the requirement standard from ASTM D 790. Figure 3.15 show the shape and geometry for flexural test specimen.

Table 3.5: Specimen dimension for flexural test

Dimensions	3-Point Flex Fixture with 5mm Radius Anvils
Width, w	13mm
Thickness, t	3mm
Length, l	125mm

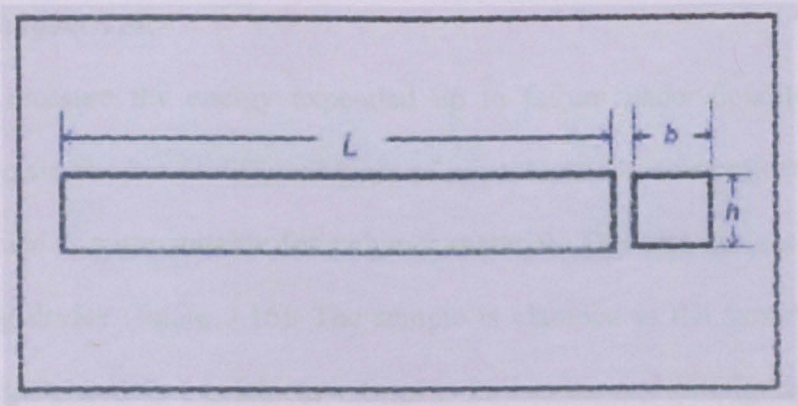


Figure 3.15: Geometry for flexural test specimen.

Procedures

[1] The width, depth and length of specimen are measured using micrometer. The support span is adjusted to 50mm as required by the standard.

[2] The loading nose and the support spans are aligned so that the axes of the cylindrical surface parallel and the loading nose I midway between the supports.

[3] The crosshead speed is set at 2mm/min and the value for the width and depth of the specimen is entered to the computer for calculation later.

[4] The test is started and a gauge is attached to the specimen to measures the deflection as shown on figure 3.14.

[5] Make sure the loading nose should be positioned at just touching the surface of the specimen before testing started.

All data the recorded from computer and printed as shown in Appendix B

3.4.5 Izod Impact Test

Impact tests measure thy energy expended up to failure under conditions of rapid loading. There are number of different types of impact test. For this project we are focus on Izod test which more suitable for polymer material. This test utilizes a pendulum-impact testing device (figure 3.16). The sample is clamped in the sample holder in a vertical. The samples have a notch cut in them to initiate the rupture (figure 3.17).

Figure 3.16: Impact Tester

Figure 3.17: Sample Notcher Machine (CSI CS-93)

The specimens used in this test are the injection molded impact specimen that is provided into the necessary dimensions. Izod impact test specimen follows the ASTM D 256 standard testing. The geometry and the dimension showed in table 3.6 and figure 3.18.

Table 3.6: Specimen dimension for Izod impact test.

Dimensions	(mm)
Length from notch to the end, B	62.5
Length, C	125
Notch depth, D	2
Thickness near the notch, E	12
Width of notch, W	6

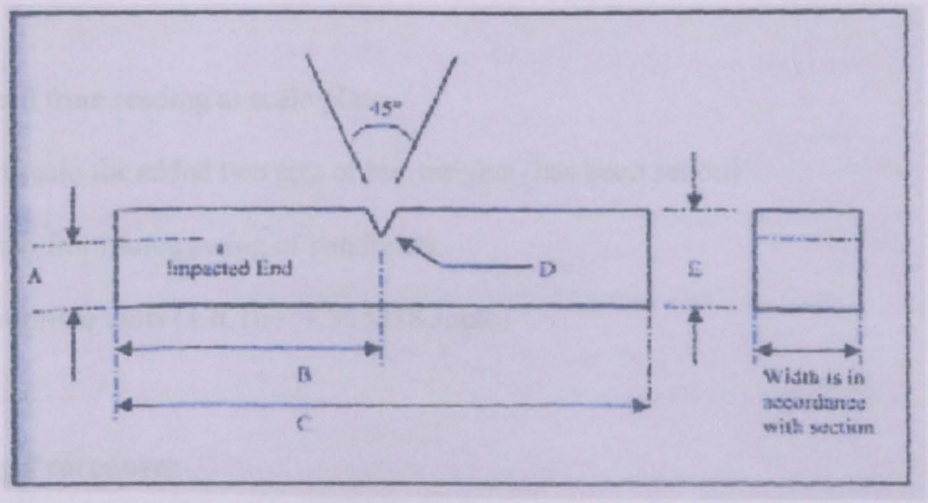


Figure 3.18: Geometry for Izod impact test specimen.

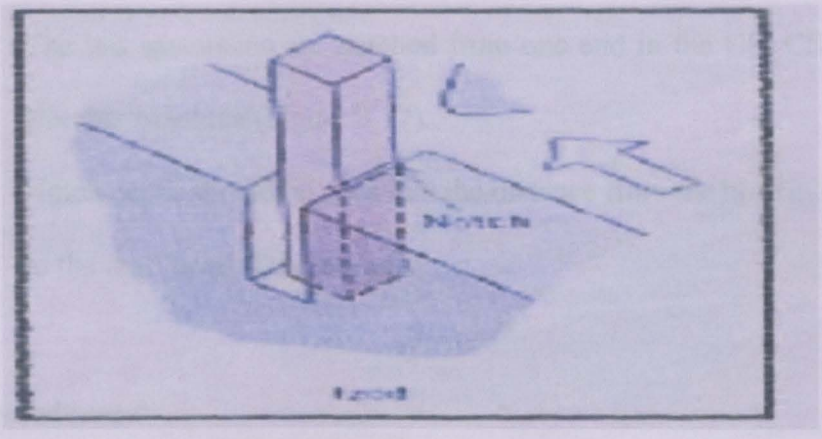


Figure 3.19: Izod impact test geometry

Formulation for Izod test:

Impact strength $I_o = E_c / w.t$

$E = E_r - E_o$

$T = L - d$

E_r = Absorbed energy

E_o = Energy loss read at scale

T = Difference

L = Thickness near notch

D = notch depth

Notes:

E_r obtained from reading at scale plate

Use third scale for added two sets of bar weights (has been set on)

E_o obtained from force swing of pendulum

Use appropriate units (1 ft.1b = 1.355818 Joule)

Notching Procedures

[1] The test specimens are conformed to the dimensions and geometry shown as in figure.

[2] The test specimens are notched from one end in the CSI CS-93 Sample Notcher Machine (Figure 3.17).

[3] Notch depth should be such that the distance from the bottom of the notch to the rear faces of the samples.

Izod Test Procedures

[1] The notch angle of test specimen should be 22.5°C.

[2] The dimensions of the specimen are measured with a micrometer and readings are recorded to the nearest 0.01 mm.

[3] First, take reading from free swing of pendulum (without specimen) and recorded as E_o.

[4] Position the specimen precisely and rigidly but not to tightly clamped in the vise (see Figure 3.19).

[5] The pendulum is released and records the excess energy remaining in the pendulum after breaking the specimens as E_r.

[6] Repeat the procedure for eight specimens.

All data then recorded and printed as shown in Appendix C.

CHAPTER 4

RESULT AND DISCUSSION

CHAPTER 4

RESULT AND DISCUSSION

4.1 Differential Scanning Calorimeter (DSC)

Differential scanning calorimetry (DSC) is a technique we use to see whether the polymer blends PP/NR with additives are compatibility or not when they are heated. It can be used to study what we call the thermal transitions of a polymer where the changes take place in a polymer when heated or we to find the melting point of polymer.

In this project, we decide whether the polymer blends are miscible or not (immiscible) by using DSC analysis. As we know from the theory, when two or three polymer mixed or blended together, the blends could be miscible or immiscible. Since the two or three components are phase separated, they retain their separate T_g *or* T_m. In fact, scientists often measure the T_g and T_m of a blend to find out if whether it is miscible or immiscible. When the DSC shows more than one peak of T_g *or* T_m on the graph, it tells that the polymer blend is a immiscible blend and when one peak of T_g *or* T_m shown on DSC graph, it means that the polymer blend is a miscible or compatible blend.

The results obtained by DSC test are summarized in the table below:-

Table 4.1: DSC results of melting temperature T_m (°C)

Batch	T_m (°C)
1 (100%PP)	157.00 °C
2 (80%PP,20%NR,0.5%DCP,3%HVA-2)	159.00 °C
3 (70%PP,30%NR,0.5%DCP,3%HVA-2)	157.67 °C
4 (50%PP,50%NR,0.5%DCP,3%HVA-2)	155.33 °C
5 (30%PP,70%NR,0.5%DCP,3%HVA-2)	151.67 °C

From DSC analysis result as shown in Appendix A and table 4.1 above, it is indicated that all batches of polymer blends are compatible because there have show one melting point, T_m.

4.2 Morphology of Polymer Blends

Blending of polymer PP/NR is incompatible. From this thesis, the technological compatibilization was sought by the addition of dicumyl peroxide (DCP) and N.N-m-phenylenebismaleimide (HVA-2). The morphology of the blends was investigated by Scanning Electron Microscopy (SEM) from the appearance of the fracture surfaces. The SEM picture for various batches PP/NR blends are shown in Appendix A.

From results SEM, it is shown that the phase of polymer natural rubber (NR) and polypropylene (PP) can absorb between each other in the polymer blends PP/NR. So, from this result, we can assume that all batch of polymer blend PP/NR are compatibility. It is indicates that, DCP and HVA-2 was also shown to be an effective compatibilizer by reducing the interfacial tension and improving adhesion between incompatible polymers PP/NR , thus produced the compatibility of the blends.

4.3 Tensile Test

Tensile test is one of the most important tests that have to be performed in order to find out the mechanical properties of certain materials. From the tensile test data in Appendix B and the proceeding chapters, it can be established that the tensile properties of yield, tensile and break strength and percent elongation at break of the test specimens are significantly dependent on its molecular configuration.

4.3.1 Yield, Tensile and Break Strength

The average strength of each material at yield, peak and break are summarized from Appendix B, can be seen in Table 4.2 below.

Table 4.2: The average Yield, Tensile (Peak) and Break strength

Batch	Yield Strength (MPa)	Tensile Strength (MPa)	Break Strength (MPa)
1 (100%PP)	13.591	28.870	17.286
2 (80%PP,20%NR,0.5%DCP,3%HVA-2)	8.029	16.590	15.922
3 (70%PP,30%NR,0.5%DCP,3%HVA-2)	6.114	12.376	12.163
4 (50%PP,50%NR,0.5%DCP,3%HVA-2)	3.791	8.662	8.320
5 (30%PP,70%NR,0.5%DCP,3%HVA-2)	1.996	5.187	5.067

The ***stress at yield*** or ***yield strength*** is the stress level at which an elastic-plastic deformation occurs. The magnitude of the yield strength of a specimen is therefore a measure of its resistance to plastic deformation, and is given by:

$$\sigma_y = W / A_o$$

where; σ_y = yield stress, W = load at yield and A_o = original cross-sectional area.

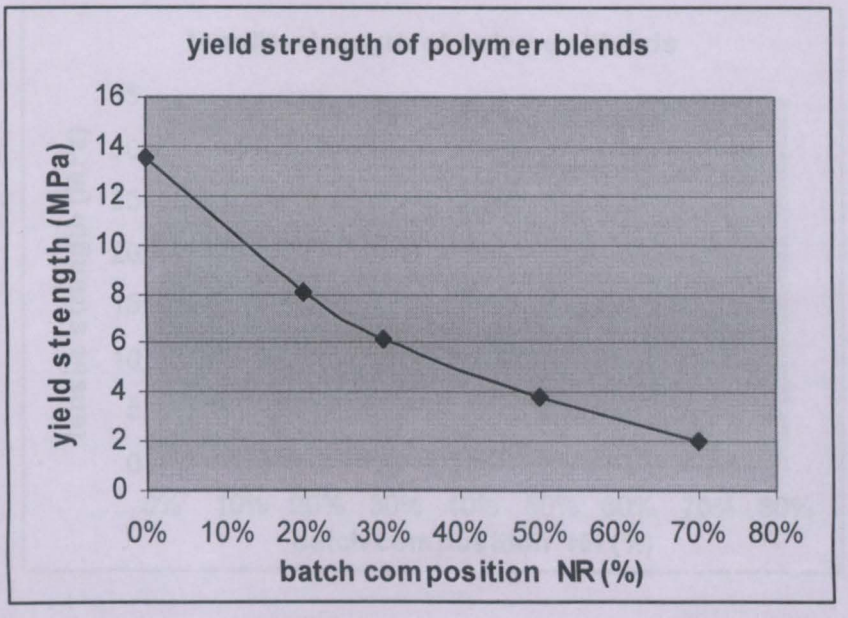


Figure 4.1: A comparison of yield strength for polymer blends

From the Table 4.2 and figure 4.1, it can be seen that the average yield strengths decrease as the percentages of natural rubber (NR) increase. It can be concluded that, the increase in percentages of the rubber content would soften the polymer blends PP/NR.

The ***tensile*** or ***peak strength*** is defined as the stress at the maximum point on the engineering stress-strain curve, as given by:

$$\sigma_m = W / A_o$$

where; σ_m = tensile stress, W = load at peak and A_o = original cross-sectional area.

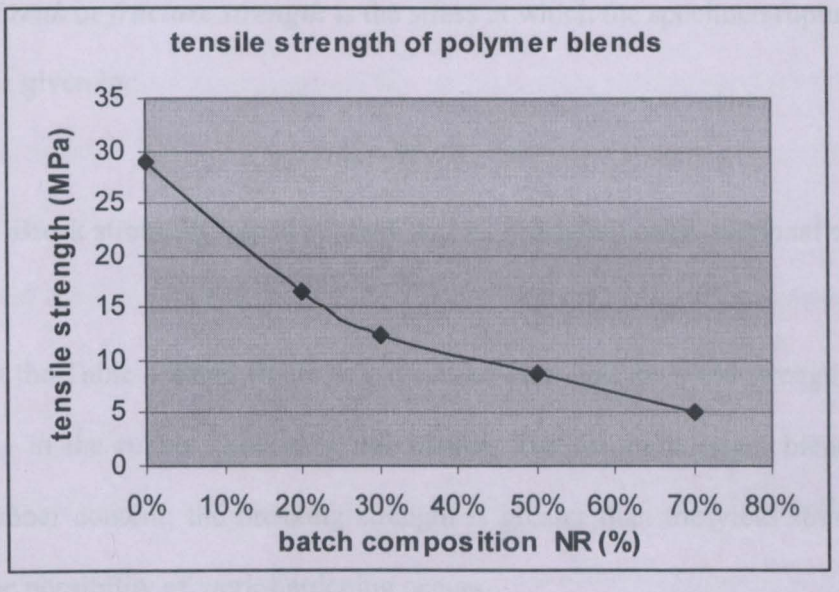


Figure 4.2: A comparison of tensile strength for polymer blends

Tensile strength is the maximum engineering stress, in tension, that may be sustained without fracture or also known as ultimate tensile strength. Results of this test are shown in figure 4.2. From the graph above, the tensile strength decrease gradually with addition of rubber into the PP matrix. This phenomenon indicating the NR was compatible enough to dissolve to some extense in the continuous PP matrix thus softens the material and lowering its rigidity.

The ***break*** or ***fracture strength*** is the stress at which the specimen ruptures or breaks, and is given by:

$$\sigma_U = W / A_o$$

where; σ_U = Break stress, W = load at break and A_o = original cross-sectional area.

From the Table 4.2 and figure 4.3, it can be seen that the yield strength decrease with increase in the rubber content in this blends. The results polymer blends PP/NR with high rubber content; the breaking strength is greater than the yield strength. This indicating the possibility of work-hardening occurs.

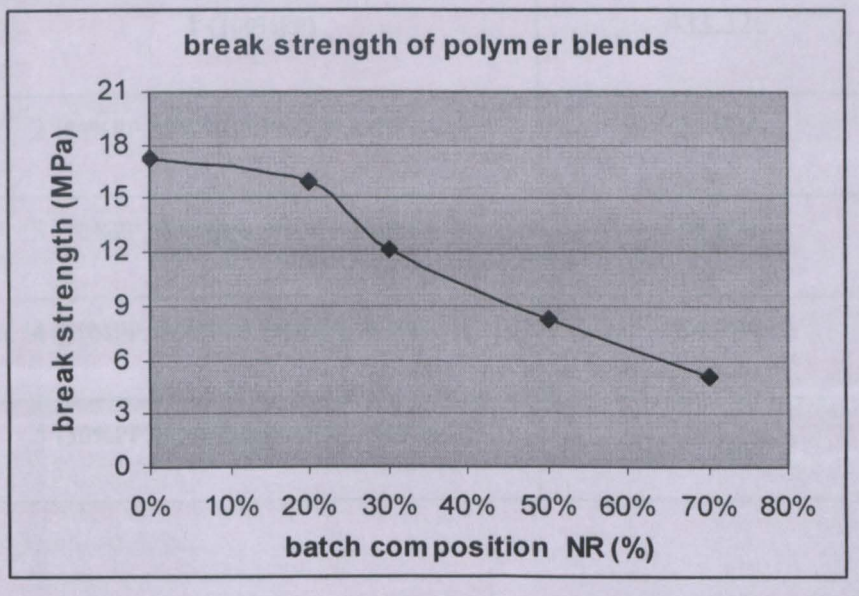


Figure 4.3: A comparison break strength for polymer blends

4.3.2 Elongation at Breaks

The elongation at break is the elongation of a test specimen expresses as a percent of the gage length. Therefore, the elongation at break, or strain at break, is the elongation of a specimen when it ruptures, or the plastic strain at fracture. The elongation at break of a material can be used as a measure of the ductility of the material and is represented by:

$$\%EL = \frac{\text{Elongation at Break}}{\text{Original Gage Length}} \times 100$$

Table 4.3: The average percent of elongation at break for test specimens

Batch	Elongation at Break, %
1 (100%PP)	433.326
2 (80%PP,20%NR,0.5%DCP,3%HVA-2)	25.731
3 (70%PP,30%NR,0.5%DCP,3%HVA-2)	19.871
4 (50%PP,50%NR,0.5%DCP,3%HVA-2)	54.739
5 (30%PP,70%NR,0.5%DCP,3%HVA-2)	108.352

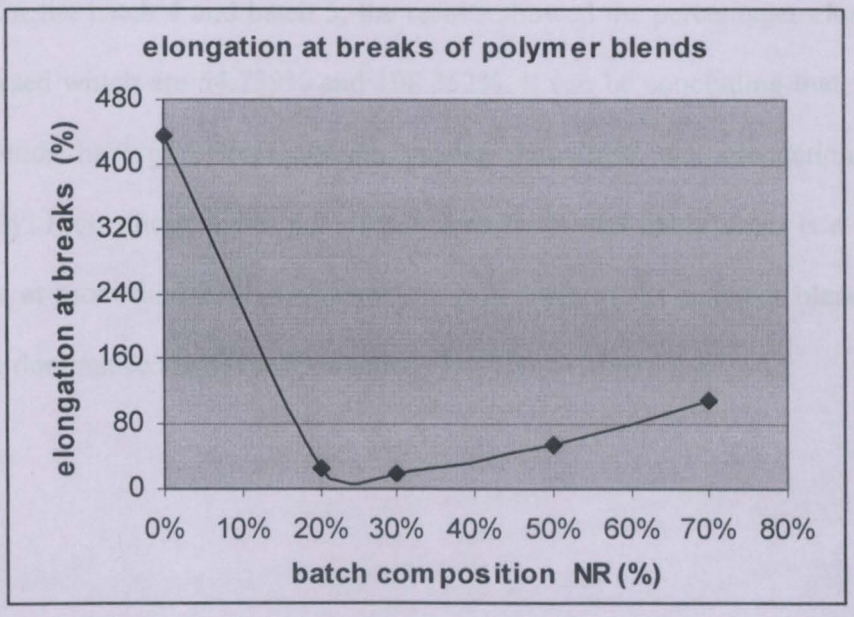


Figure 4.4: A comparison of elongation at breaks from polymer blends

The results for this test are shown in the Figure 4.4. The figure shows that, the average percentages of elongation at break for batch 1 (100% PP) is 433.326%. The percentages of elongation at break decrease immediately when 20% NR and less than 30% NR is added to batch 2 and batch 3. The value of the batch 2 is 25.731% and batch 3 is 19.871. It indicate, PP has ductility of the material and when the small percentages NR dispersed in the blends, PP/NR can give properties ductile to brittle, so the sample is lowest elongation at break.

As for the batch 4 and batch 5, the results showed the percentages elongation at break increased which are 54.739% and 108.352%. It can be concluding that, when the polymer blends having rubber contents greater than 25%, the elongation increase exponentially. From these figure 4.4, it indicates that most likely there is a transition composition at more than 25% NR where the properties of the polymer blends change from plastic dominance to rubber dominance.

4.4 Flexural Properties

Flexural modulus is a measure of stiffness during the initial stage of the bonding process. In many cases, it is equal to the tensile modulus which is determined by calculating the slope of the initial straight line in the stress-strain diagram.

The averages flexural modulus of the test specimens for batch 1 to 5 is shown in table 4.4:

Table 4.4: The average value of flexural modulus of test specimens from different batch of polymer blends

Batch	Flexural modulus (MPa)
Batch 1	567.982
Batch 2	505.150
Batch 3	364.738
Batch 4	174.665
Batch 5	93.04

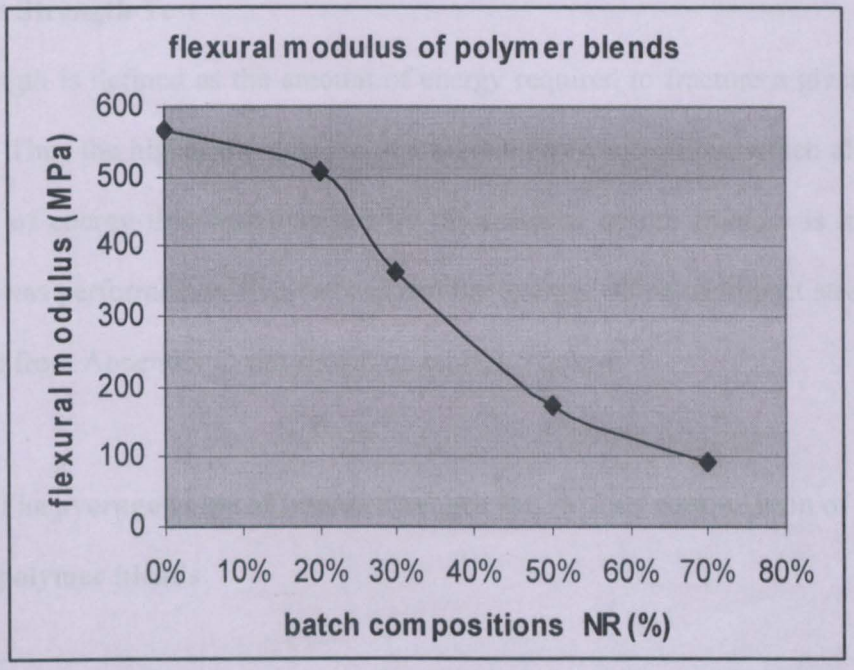


Figure 4.5: Comparison of flexural modulus of polymer blends

From the table 4.4, the flexural modulus batch 1 (100% PP) is highest stiffness compared to another 4 batch polymer blends PP/NR. The flexural modulus for batch 1 is 567.982 MPa. For batch 2, the flexural modulus is 505.150 Mpa and Batch 3, 4 and 5 for flexural modulus to shown the lower stiffness to follow the batch compositions which are 364.738 MPa, 174.665 MPa and 93.04 Mpa.

It can be seen that from the figure 4.5, the flexural modulus decrease with increase in the rubber content in the blends. This indicates that the natural rubber was compatible enough to dissolve to some extent in the continuous PP matrix, softening it and lowering its rigidity.

4.5 Impact Strength Test

Impact strength is defined as the amount of energy required to fracture a given volume of material. Thus the higher the value is, the more energy is required which also means the amount of energy that was obtained by the material before fracture is more. The impact test was performed on five batches and the average value of impact strength was summarized from Appendix C and shown on table 4.5 below.

Table 4.5: The average value of impact strength for various composition of polymer blends

Batch	Impact Strength (KJ/m^2)
Batch 1 (100%PP)	6.733
Batch 2 (80%PP,20%NR,0.5%DCP,3%HVA-2)	7.443
Batch 3 (70%PP,30%NR,0.5%DCP,3%HVA-2)	8.904
Batch 4 (50%PP,50%NR,0.5%DCP,3%HVA-2)	13.955
Batch 5 (30%PP,70%NR,0.5%DCP,3%HVA-2)	17.456

The impact test was carried out on the Mosanto Impact Testing Machine. Since what interest us is to find out by what percentage had the impact strength improved with the addition of rubber, a graph of relative impact strength of polymer blends was plotted against the batch composition as shown in figure 4.6.

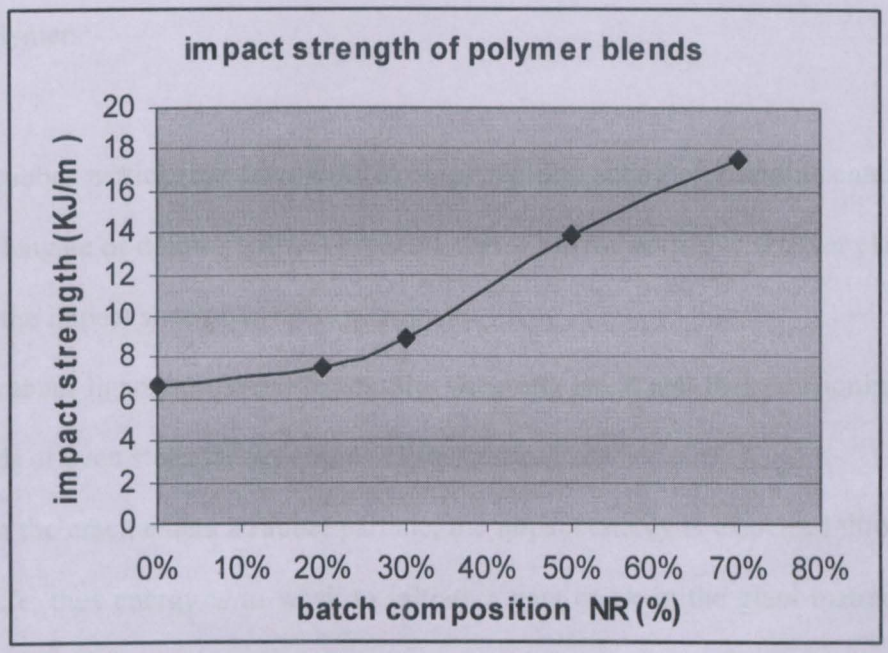


Figure 4.6: A comparison of relative impact strength of polymer blends

From figure 4.6 above, it can be seen that the impact strength of the polymer blends increase with increase into the rubber content in the blends. It indicates that, when PP/NR is compatible, there will be interfacial adhesion formed between the two phases. Interfacial adhesion formed by the addition of DCP and HVA-2 is the most important factor for the impact strength improvement. This can be explained through the

fact that in compatibilized blend process, graft copolymer and crosslinked structure are formed in the natural rubber, thus increase the impact strength of PP/NR blends. The subject of improving the impact strength of a glassy matrix such as PP by introducing the rubber phase into the matrix had been widely studied by many researchers. Below are a number of theories for impact improvement of glassy plastic by blending with rubbery polymers:-

a) The rubber particle has the ability to relax rapidly, acting as a strain center which can elongate or deform without breaking and it has the ability to recover elastically after the impact shock wave has passed.

b) The rubber ligaments stretch across the widening crack and their tensioning effect retards or even stops the separation of the crack.

c) When the crack enters a rubber particle, the impact energy is dispersed through the particle, thus energy is to weak to initiate a new crack in the glass matrix at that point.

d) The crack tears away the rubber from the matrix and creating more new surfaces which use up a large amount of energy as the surface energy. Thus there is not enough mechanical energy left for the crack to propagate.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The blends of PP/NR with additives such as dicumyl peroxide (DCP) and co-agents is N.N-m-phenylenebismaleimide (HVA-2) basically is for producing a new material. The incorporation of natural rubber in polypropylene is extensively used for improving impact strength of the material. In this thesis project, the result shows impact strength of the blends increased with increasing the natural rubber content in the blends but the mechanical properties such as yield strength, tensile strength, break strength and flexural modulus decreased gradually.

In this study, the DCP and HVA-2 was also shown to be an effective compatibilizer by reducing the interfacial tension and improving adhesion between PP/NR polymers, thus increasing the compatibility of the blend. So, the impact strength of this natural rubber can be modified by plastic blend, which is dependent on good adhesion and is improved by a low degree of crosslinking in the rubber phase.

5.2 Recommendation

From the thesis project, I would like to make recommendation for improvement in the future research. The recommendation is as follows:

- In present work, for PP/NR blends, since the impact strength was fluctuating with respect to percentages of natural rubber added, it is recommended to carry out some test for higher percentages of natural rubber. As for PP/NR blends, future tests should be concentrated on adding of low percentages of natural rubber (less than 20%) into the matrix material polypropylene (PP).

- This present thesis would also like to suggest that asbestos fibers and glass fibers should be added of PP/NR blends to obtain higher mechanical properties such as tensile strength, flexural modulus, yield strength and etc. because it can overcome the reduction of mechanical properties PP/NR blends.

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APPENDIX

APPENDIX A

- DIFFERENTIAL SCANNING CALORIMETER RESULTS
- SCANNING ELECTRON CALORIMETER RESULTS

APPENDIX B

- TENSILE TEST RESULTS
- FLEXURAL TEST RESULTS

APPENDIX C

- IZOD IMPACT TEST RESULTS

APPENDIX A

DIFFERENTIAL SCANNING CALORIMETER RESULTS:

[Batch 1]

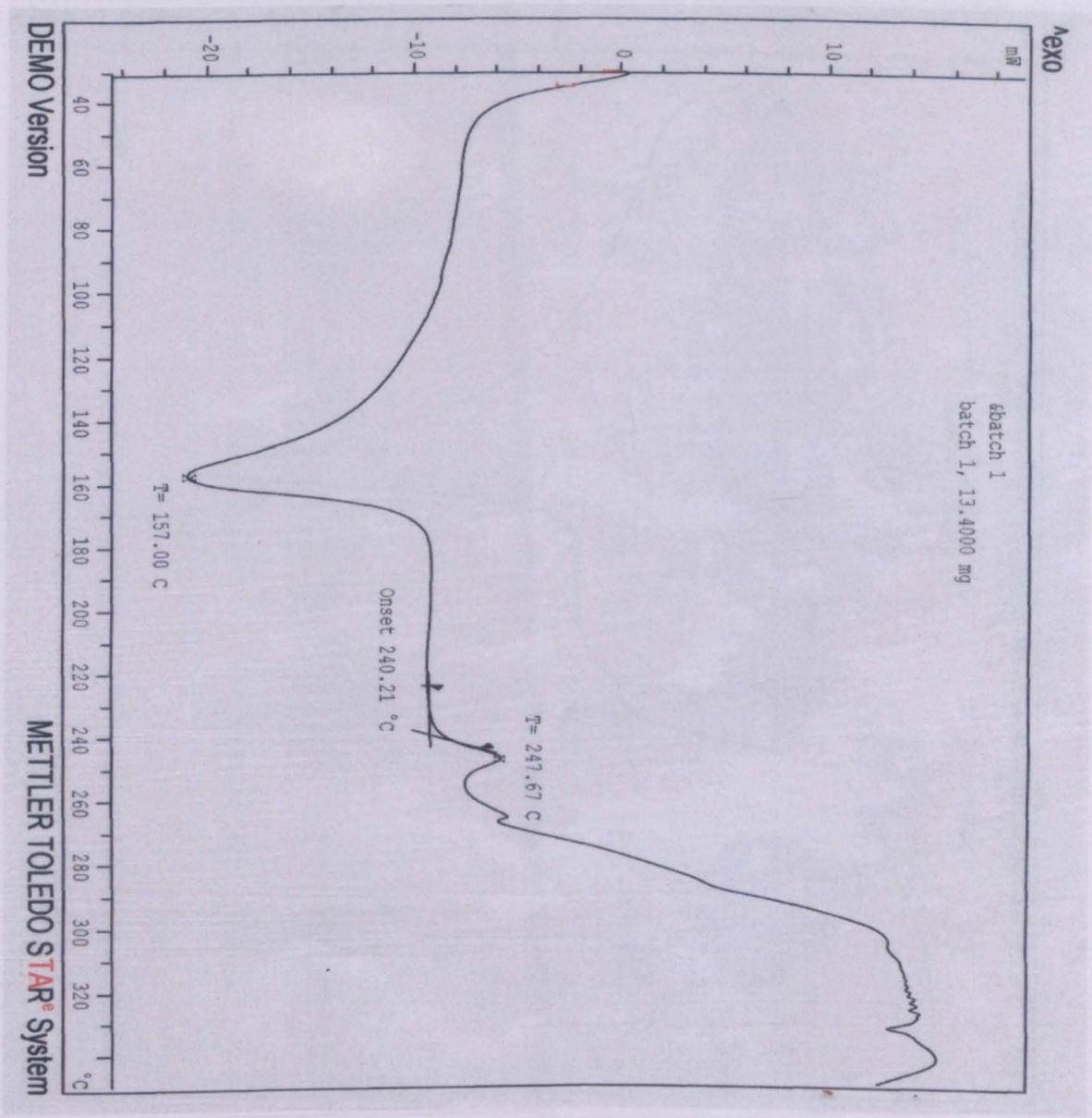

Figure A-1: DSC Result for Batch 1

[Batch 2]

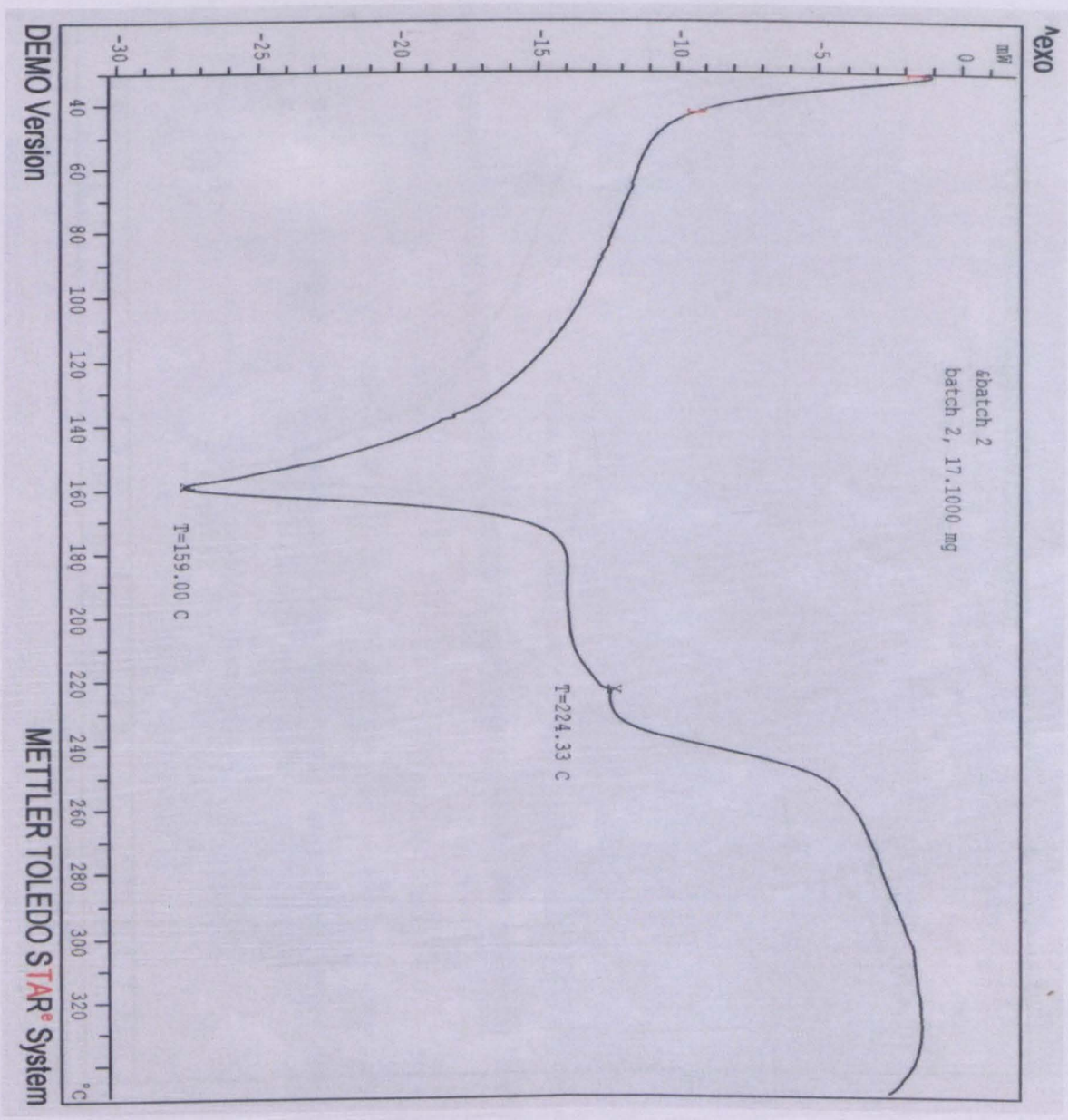

Figure A-2: DSC Result for Batch 2

[Batch 3]

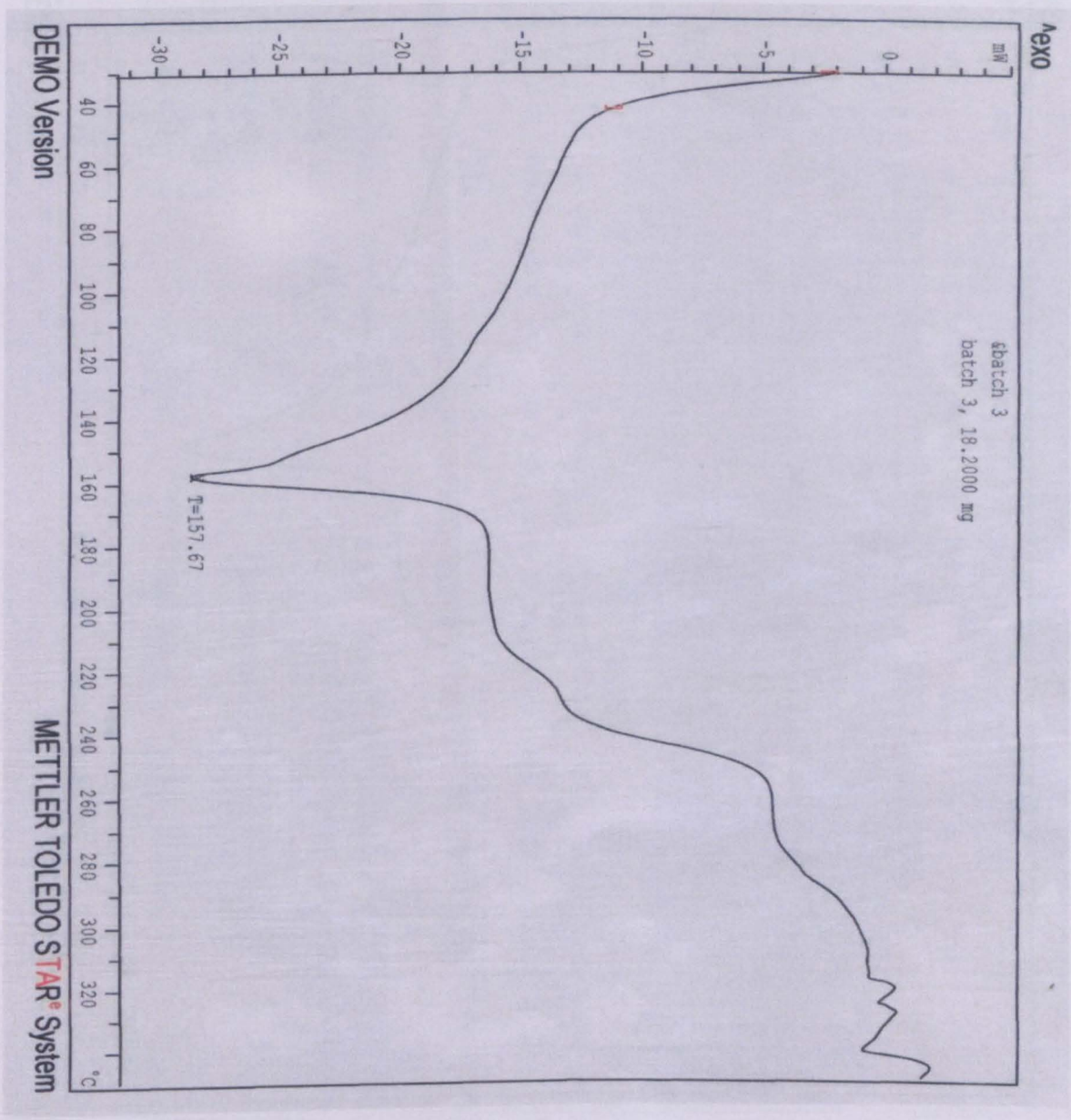

Figure A-3: DSC Result for Batch 3

[Batch 4]

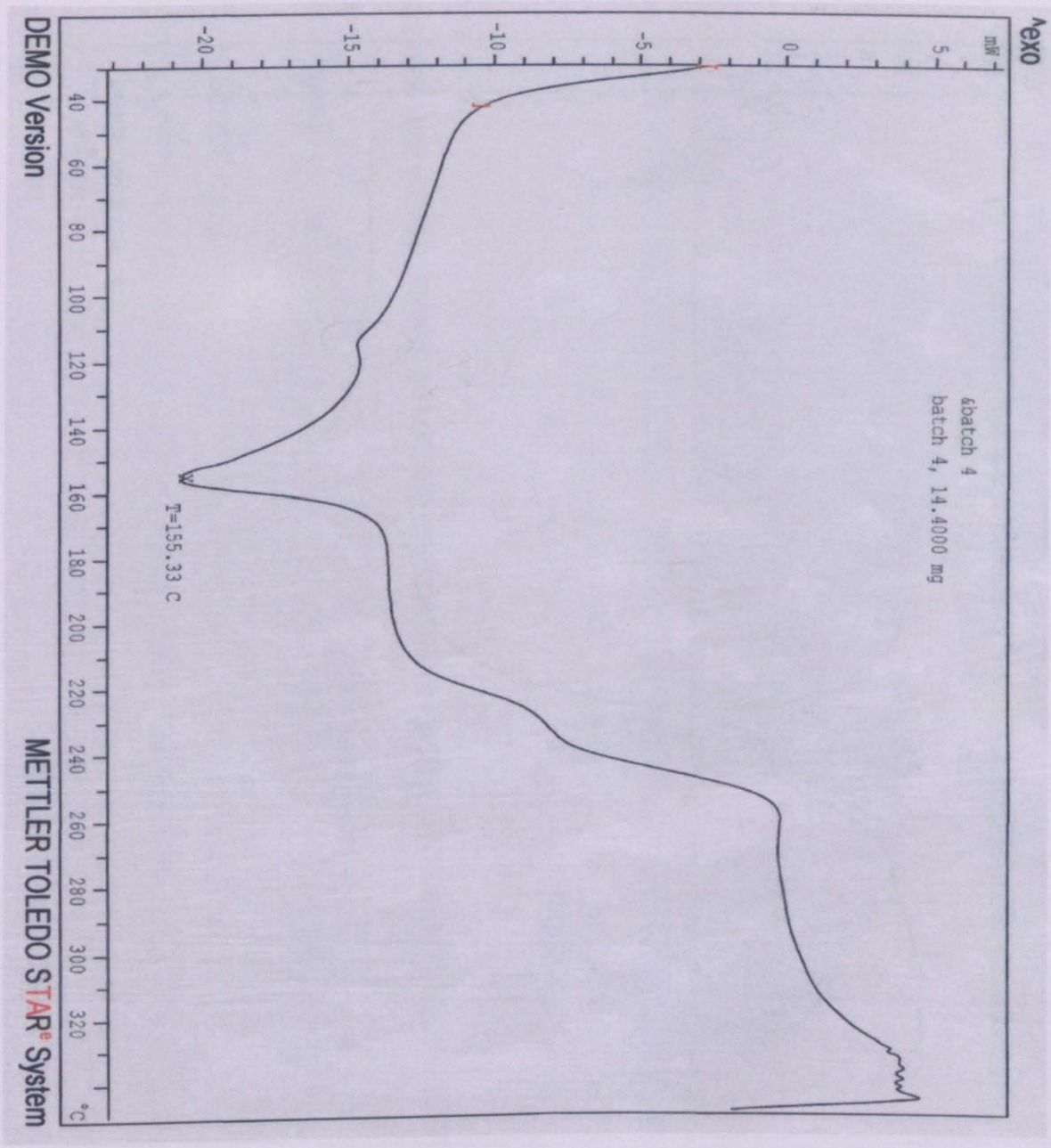

Figure A-4: DSC Result for Batch 4

[Batch 5]

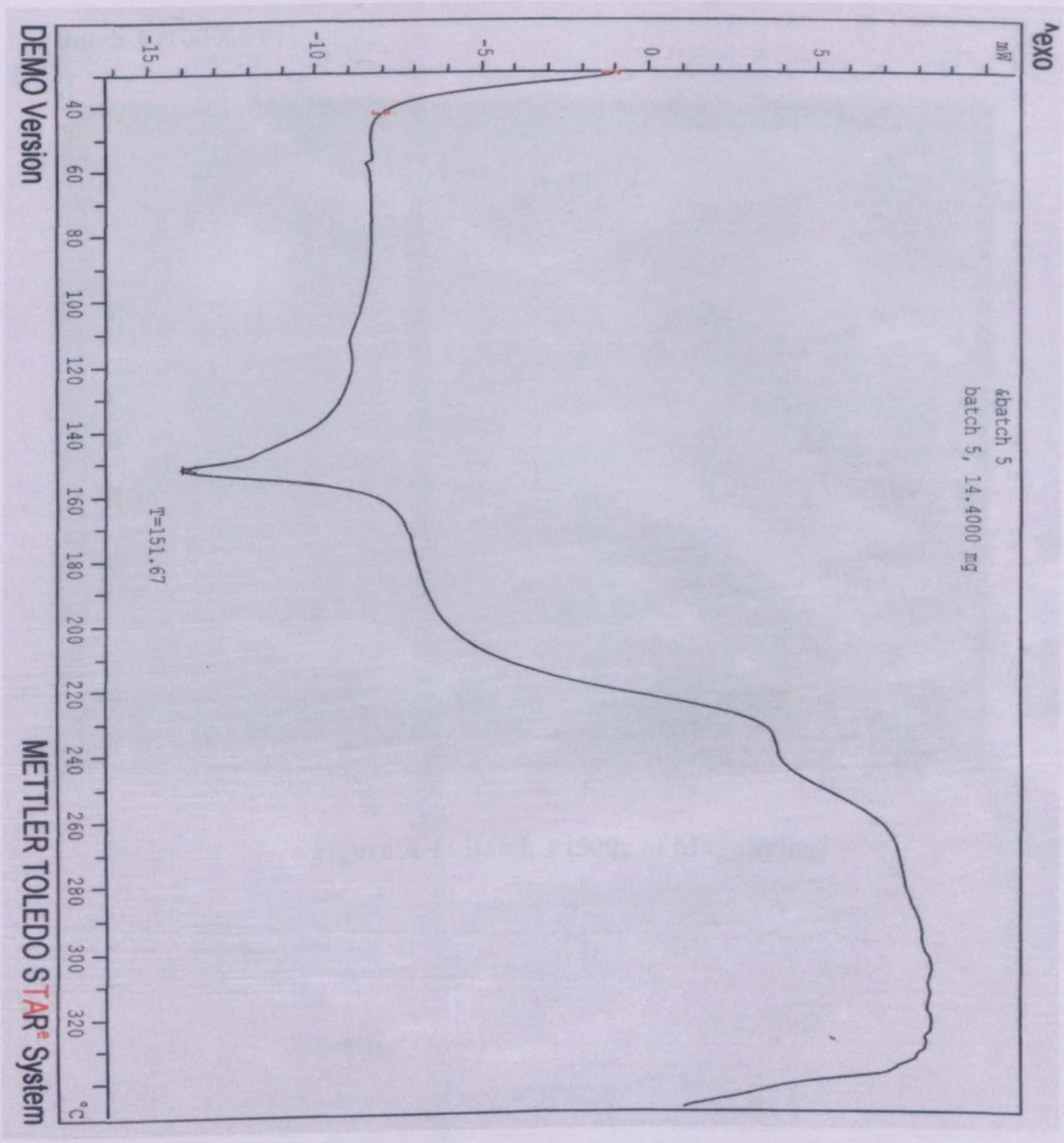

Figure A-5: DSC Result for Batch 5

SCANNING ELECTRON MICROSCOPE RESULTS

Batch 1 (100%PP)

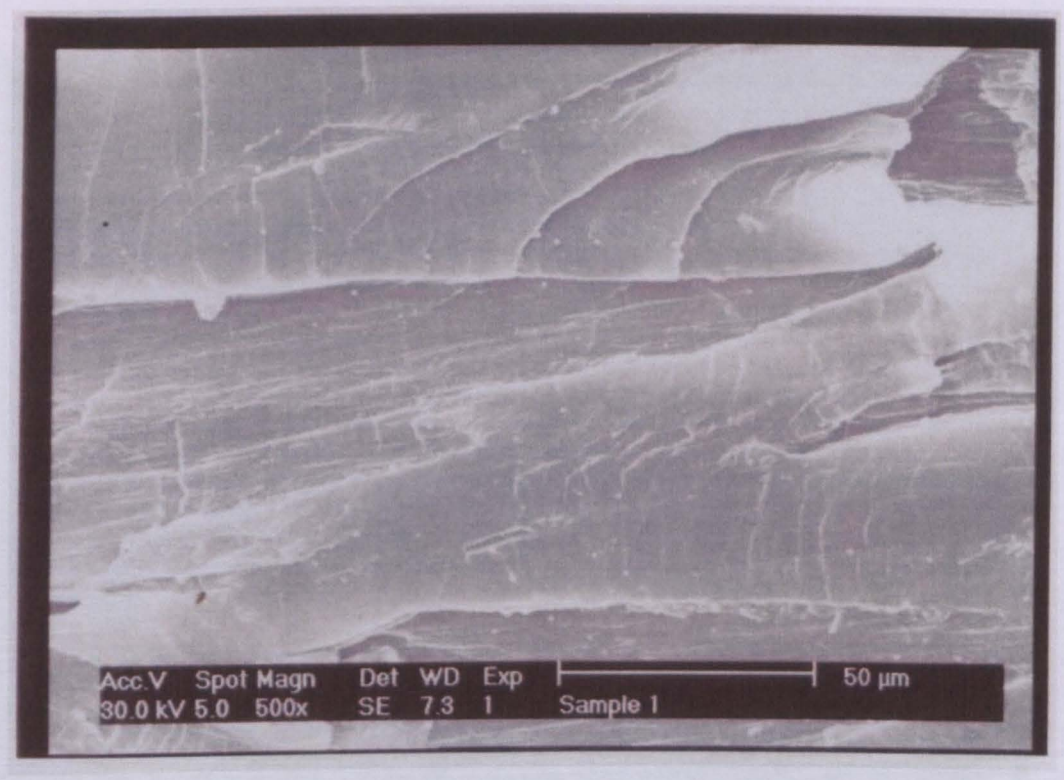

Figure A-6: Batch 1 (500x of Magnifying)

Batch 2 (80%PP, 20%NR, 0.5%DCP, 3%HVA-2)

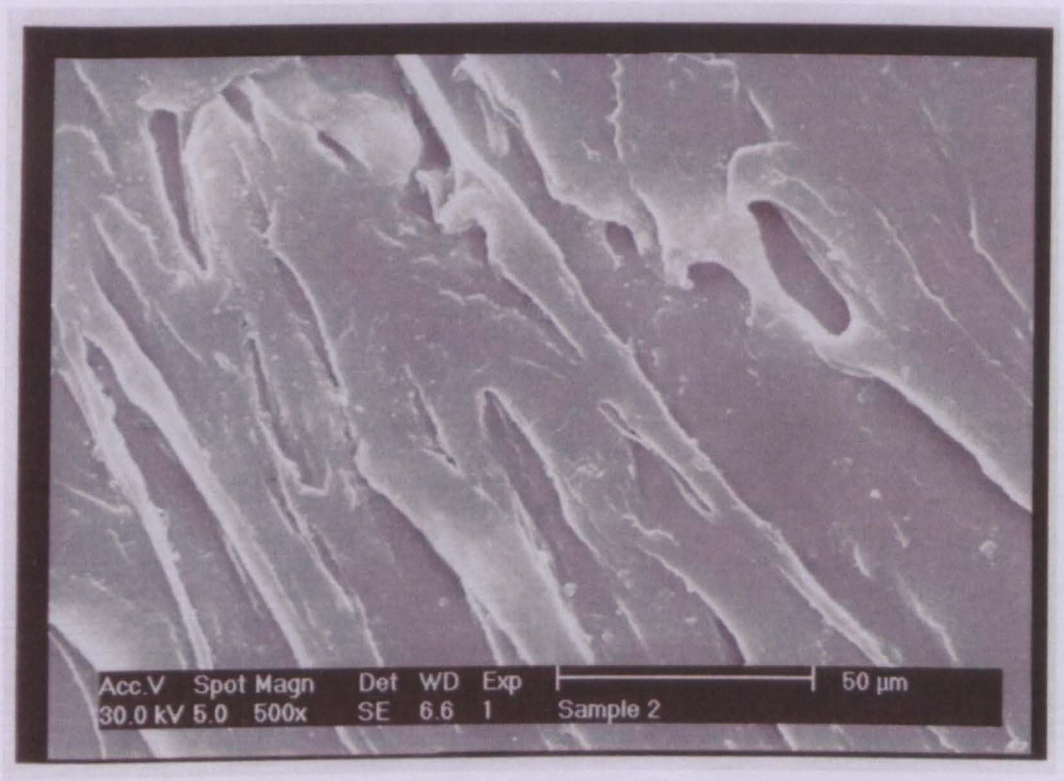

Figure A-7: Batch 2 (500x of Magnifying)

Batch 3 (70%PP, 30%NR, 0.5%DCP, 3%HVA-2)

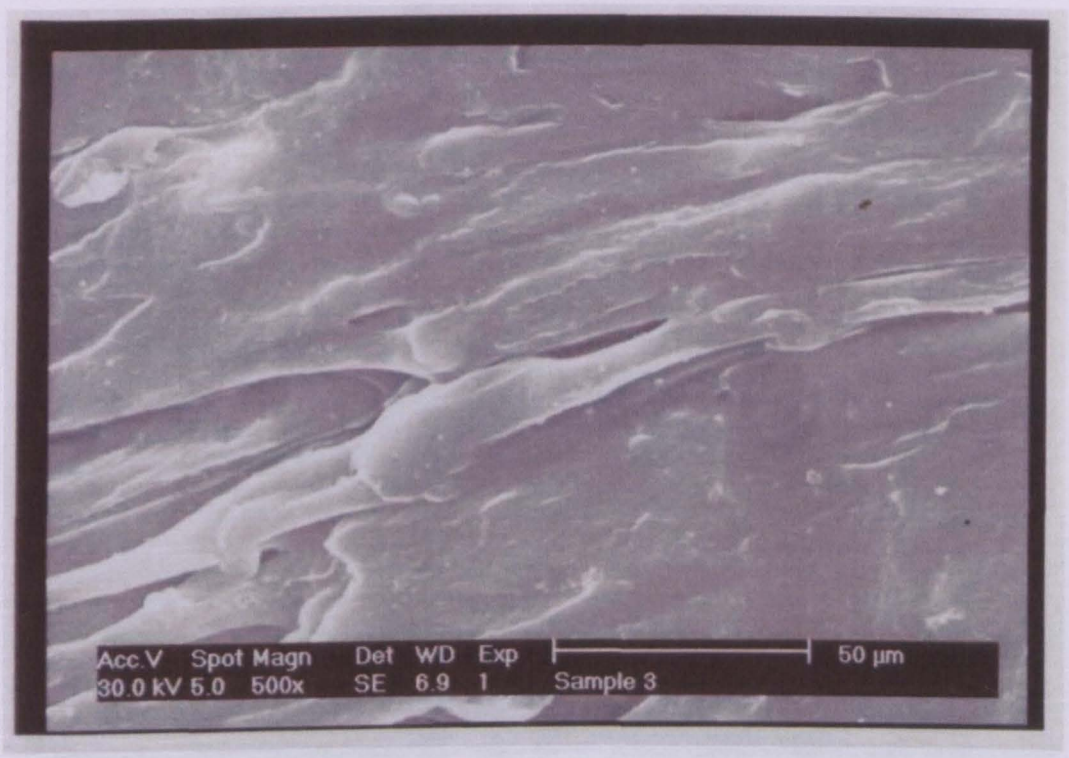

Figure A-8: Batch 3 (500x of Magnifying)

Batch 4 (50%PP, 50%NR, 0.5%DCP, 3%HVA-2)

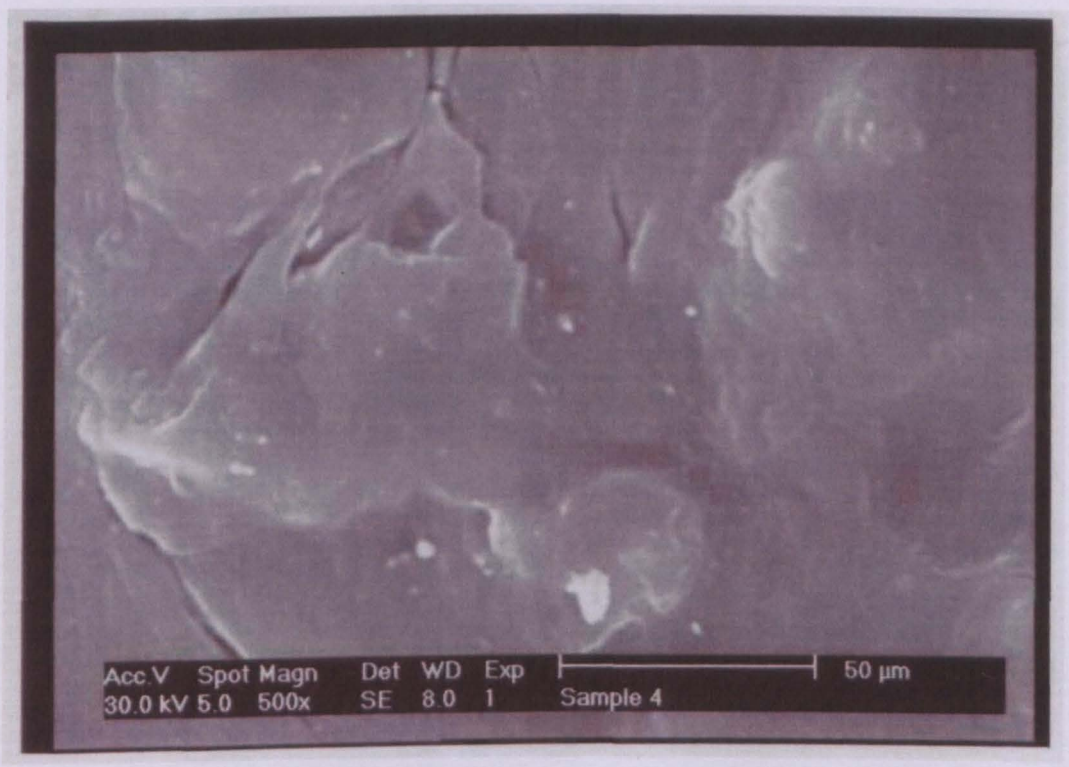

Figure A-9: Batch 4 (500x of Magnifying)

Batch 5 (30%PP, 70%NR, 0.5%DCP, 3%HVA-2)

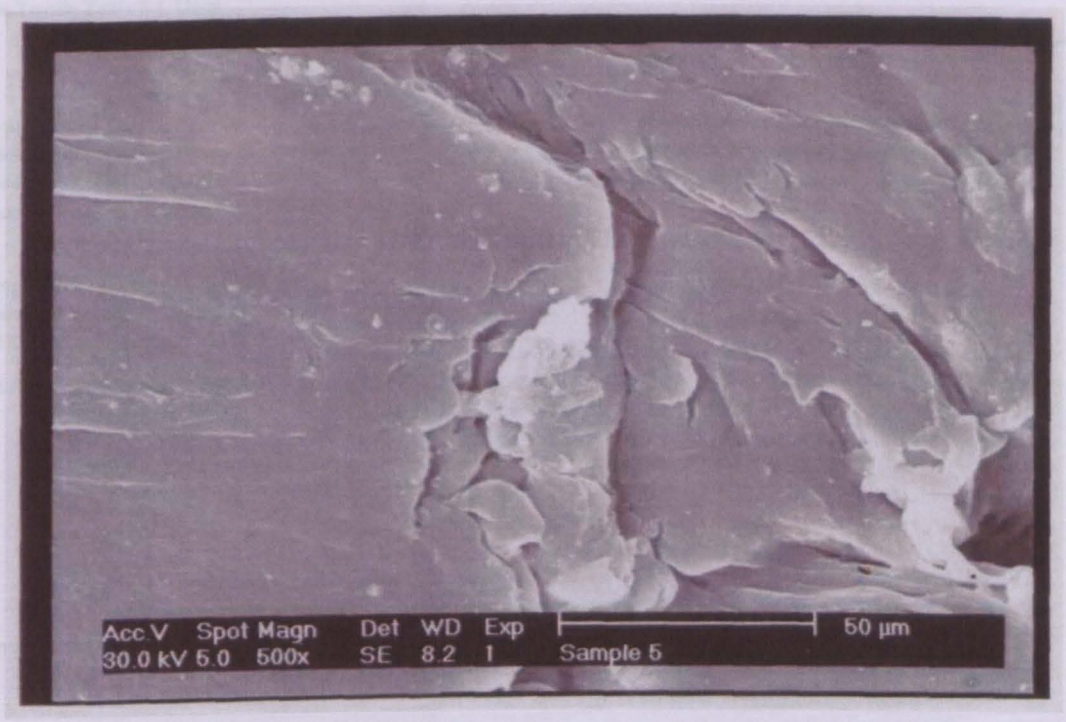

Figure A-10: Batch 5 (500x of Magnifying)

APPENDIX B

TENSILE TEST RESULTS:

Table B-1: Tensile Test Results of Batch 1

MAKMAL SAINS BAHAN
JABATAN MEKANIK & BAHAN
UNIVERSITI MALAYA

Plastics Tensile Test - S.I. Units

Test type: Tensile
Operator name: Operator
Sample Identification: NRPP
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Wednesday, January 01, 2005

Sample Rate (pts/secs): 6.6670
Crosshead Speed: 45.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 10.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (kN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (kN)	LASE 1% (kN)	LASE 2% (kN)
1	10.955	21.911	1.111	27.782	253.685	507.371	0.642	0.203	0.387
2	10.627	21.253	1.129	28.232	215.627	431.253	0.617	0.181	0.365
3	11.307	22.614	1.172	29.307	299.617	599.234	0.766	0.199	0.396
4	11.349	22.699	1.178	29.457	128.949	257.899	0.734	0.198	0.396
5	11.328	22.656	1.160	29.007	198.058	396.116	0.714	0.194	0.389
6	11.366	22.732	1.177	29.432	204.236	408.473	0.676	0.199	0.399
Mean	11.155	22.311	1.155	28.870	216.695	433.391	0.691	0.196	0.389
S.D.	0.301	0.603	0.028	0.702	57.354	114.708	0.057	0.008	0.013

	EASL .5 KN (%)	Load at 0.2% Yield (kN)	Stress at Break (MPa)	Young's Modulus (MPa)	Stress at 0.2% Yield (MPa)	EASL 2.5 KN (%)	Energy to Break Point (J)	Tensile Energy Absorption (N/mm)
1	2.743	0.506	16.052	499.693	12.641	-	189.099	293.177
2	2.880	0.531	15.426	458.569	13.278	-	161.851	250.931
3	2.624	0.569	19.145	501.705	14.232	-	232.137	359.902
4	2.627	0.540	18.355	501.270	13.500	-	101.280	157.023
5	2.678	0.566	17.844	490.633	14.151	-	152.753	236.827
6	2.595	0.550	16.897	504.658	13.742	-	156.899	243.254
Mean	2.691	0.543	17.286	492.754	13.591		165.670	256.852
S.D.	0.106	0.024	1.417	17.410	0.593		43.292	67.120

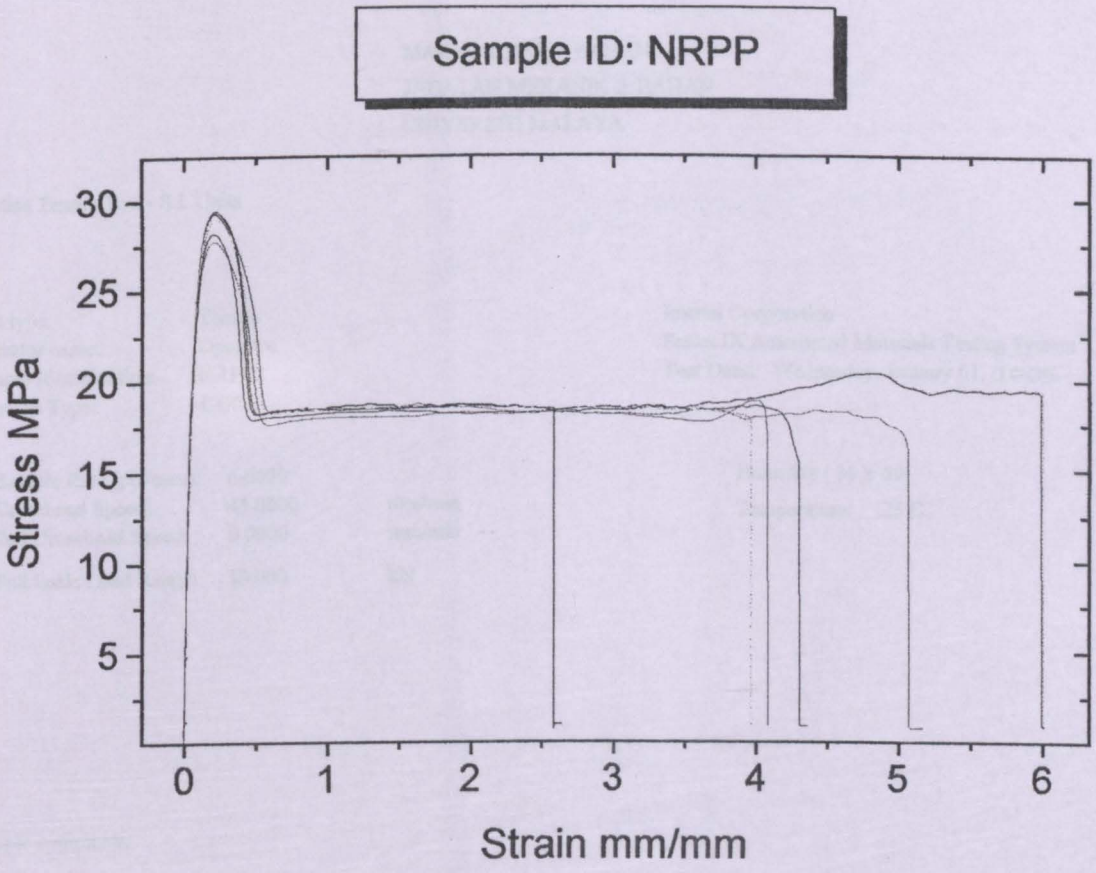

Figure B-1: Stress-Strain Diagram of Tensile Test Result of Batch 1

Table B-2: Tensile Test Results of Batch 2

MAKMAL SAINS BAHAN
JABATAN MEKANIK & BAHAN
UNIVERSITI MALAYA

Plastics Tensile Test - S.I. Units

Test type:	Tensile	Instron Corporation	
Operator name:	Operator	Series IX Automated Materials Testing System	7.51.00
Sample Identification:	NRPP2	Test Date: Wednesday, January 01, 2005	
Interface Type:	4200		

Sample Rate (pts/secs):	6.6670		Humidity (%):	50
Crosshead Speed:	45.0000	mm/min	Temperature:	23 C
2nd Crosshead Speed:	0.0000	mm/min		
Full Scale Load Range:	10.000	kN		

Sample comments:

	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (kN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (kN)	LASE 1% (kN)	LASE 2% (kN)
1	11.666	23.332	0.654	16.347	13.686	27.372	0.612	0.118	0.232
2	11.885	23.769	0.680	17.012	13.985	27.969	0.645	0.134	0.252
3	9.607	19.213	0.641	16.037	10.537	21.073	0.627	0.130	0.243
4	12.017	24.035	0.662	16.562	13.327	26.655	0.644	0.117	0.234
5	10.648	21.296	0.674	16.864	12.038	24.076	0.641	0.121	0.241
6	12.001	24.002	0.669	16.717	13.621	27.242	0.651	0.117	0.234
Mean	11.304	22.608	0.663	16.590	12.866	25.731	0.637	0.123	0.239
S.D.	0.977	1.954	0.014	0.357	1.328	2.656	0.015	0.007	0.008

	EASL .5 KN (%)	Load at 0.2% Yield (kN)	Stress at Break (MPa)	Young's Modulus (MPa)	Stress at 0.2% Yield (MPa)	EASL 2.5 KN (%)	Energy to Break Point (J)	Tensile Energy Absorption (N/mm)
1	6.321	0.326	15.299	295.296	8.150	-	7.489	11.610
2	5.805	0.307	16.124	334.060	7.673	-	8.028	12.447
3	6.386	0.275	15.681	327.499	6.887	-	5.421	8.405
4	6.239	0.332	16.112	295.546	8.291	-	7.357	11.406
5	5.902	0.338	16.037	304.622	8.445	-	6.651	10.311
6	6.140	0.349	16.279	295.188	8.727	-	7.611	11.800
Mean	6.132	0.321	15.922	308.702	8.029		7.093	10.996
S.D.	0.233	0.026	0.364	17.598	0.659		0.934	1.448

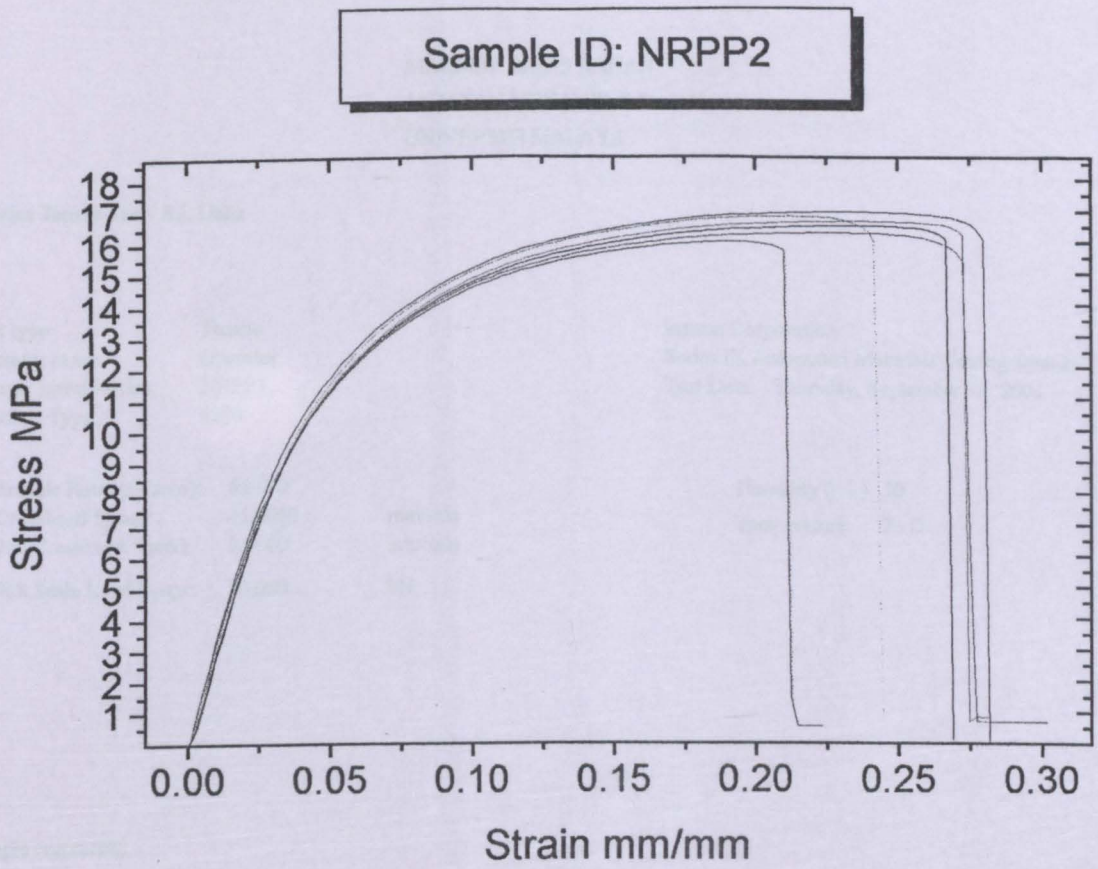

Figure B-2: Stress-Strain Diagram of Tensile Test Result of Batch 2

Table B-3: Tensile Test Results of Batch 3

MAKMAL SAINS BAHAN
JABATAN MEKANIK & BAHAN
UNIVERSITI MALAYA

Plastics Tensile Test - S.I. Units

Test type: Tensile
Operator name: Operator
Sample Identification: NRPP3
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Thursday, September 16, 2004

Sample Rate (pts/secs): 6.6670
Crosshead Speed: 45.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 10.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (kN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (kN)	LASE 1% (kN)	LASE 2% (kN)
1	8.610	17.220	0.495	12.366	8.870	17.740	0.491	0.089	0.178
2	8.929	17.858	0.503	12.581	9.529	19.058	0.492	0.098	0.187
3	10.040	20.080	0.531	13.271	10.670	21.340	0.523	0.096	0.189
4	8.974	17.948	0.453	11.333	9.604	19.208	0.442	0.081	0.163
5	9.488	18.975	0.503	12.573	10.058	20.115	0.493	0.098	0.187
6	10.132	20.265	0.485	12.131	10.882	21.765	0.476	0.084	0.170
Mean	9.362	18.724	0.495	12.376	9.935	19.871	0.486	0.091	0.179
S.D.	0.628	1.256	0.025	0.637	0.756	1.513	0.026	0.007	0.011

	EASL .5 KN (%)	Load at 0.2% Yield (kN)	Stress at Break (MPa)	Young's Modulus (MPa)	Stress at 0.2% Yield (MPa)	EASL 2.5 KN (%)	Energy to Break Point (J)	Tensile Energy Absorption (N/mm)
1	-	0.252	12.291	225.337	6.297	-	3.181	4.931
2	16.028	0.245	12.298	240.363	6.122	-	3.409	5.285
3	12.191	0.267	13.078	240.471	6.686	-	4.506	6.985
4	-	0.225	11.063	205.244	5.619	-	3.408	5.284
5	16.905	0.229	12.338	243.362	5.726	-	3.622	5.615
6	-	0.249	11.908	213.931	6.236	-	4.237	6.569
Mean	0.000	0.245	12.163	228.118	6.114		3.727	5.778
S.D.	0.000	0.016	0.660	15.919	0.393		0.525	0.814

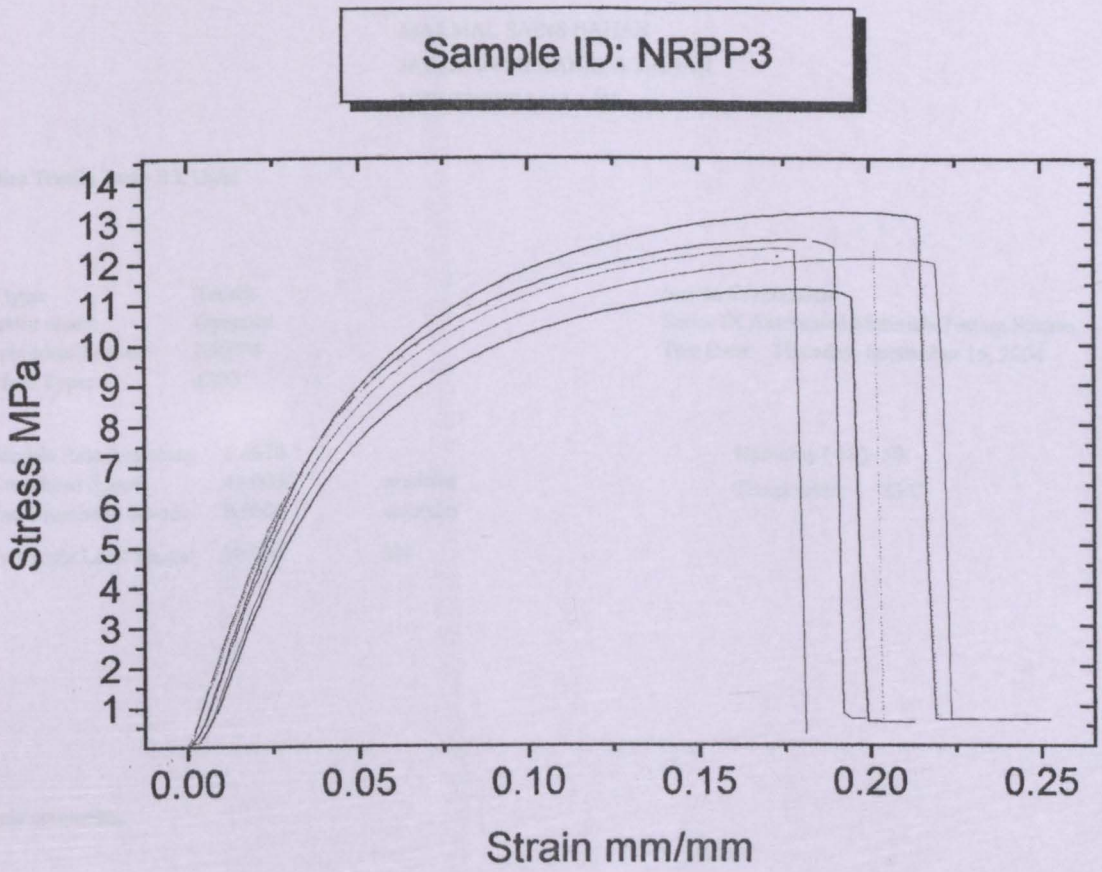

Figure B-3: Stress-Strain Diagram of Tensile Test Result of Batch 3

Table B-4: Tensile Test Results of Batch 4

MAKMAL SAINS BAHAN
JABATAN MEKANIK & BAHAN
UNIVERSITI MALAYA

Plastics Tensile Test - S.I. Units

Test type: Tensile
Operator name: Operator
Sample Identification: NRPP4
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Thursday, September 16, 2004

Sample Rate (pts/secs): 6.6670
Crosshead Speed: 45.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 10.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (kN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (kN)	LASE 1% (kN)	LASE 2% (kN)
1	27.281	54.561	0.340	8.505	29.871	59.741	0.328	0.044	0.093
2	20.643	41.285	0.337	8.417	22.213	44.425	0.325	0.047	0.097
3	23.430	46.860	0.349	8.715	26.240	52.480	0.334	0.052	0.101
4	25.695	51.390	0.359	8.975	28.585	57.170	0.346	0.051	0.104
5	26.513	53.026	0.353	8.835	28.693	57.386	0.333	0.048	0.099
6	26.336	52.673	0.341	8.525	28.616	57.233	0.331	0.046	0.097
Mean	24.983	49.966	0.346	8.662	27.370	54.739	0.333	0.048	0.098
S.D.	2.498	4.997	0.009	0.216	2.790	5.579	0.007	0.003	0.004

	EASL .5 KN (%)	Load at 0.2% Yield (kN)	Stress at Break (MPa)	Young's Modulus (MPa)	Stress at 0.2% Yield (MPa)	EASL 2.5 KN (%)	Energy to Break Point (J)	Tensile Energy Absorption (N/mm)
1	-	0.153	8.197	115.248	3.820	-	8.904	13.805
2	-	0.147	8.117	120.830	3.685	-	6.345	9.837
3	-	0.139	8.345	129.773	3.464	-	7.920	12.279
4	-	0.160	8.660	129.398	4.001	-	9.013	13.974
5	-	0.155	8.317	123.209	3.880	-	8.856	13.731
6	-	0.156	8.285	120.881	3.893	-	8.551	13.257
Mean		0.152	8.320	123.223	3.791		8.265	12.814
S.D.		0.008	0.186	5.583	0.191		1.021	1.582

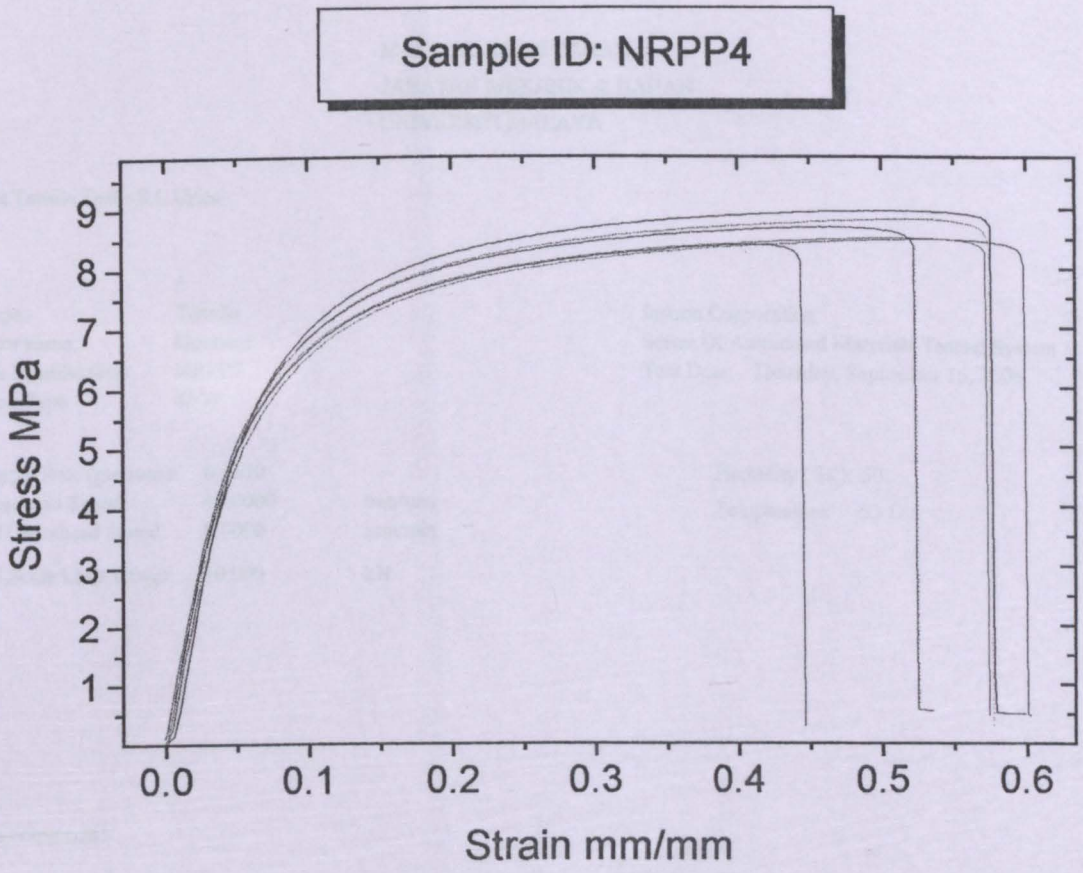

Figure B-4: Stress-Strain Diagram of Tensile Test Result of Batch 4

Table B-5: Tensile Test Results of Batch 5

MAKMAL SAINS BAHAN
JABATAN MEKANIK & BAHAN
UNIVERSITI MALAYA

Plastics Tensile Test - S.I. Units

Test type:	Tensile	Instron Corporation	
Operator name:	Operator	Series IX Automated Materials Testing System	7.51.00
Sample Identification:	NRPP5	Test Date: Thursday, September 16, 2004	
Interface Type:	4200		

Sample Rate (pts/secs):	6.6670		Humidity (%):	50
Crosshead Speed:	45.0000	mm/min	Temperature:	23 C
2nd Crosshead Speed:	0.0000	mm/min		
Full Scale Load Range:	10.000	kN		

Sample comments:

	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (kN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (kN)	LASE 1% (kN)	LASE 2% (kN)
1	45.590	91.179	0.202	5.054	47.350	94.699	0.196	0.024	0.045
2	41.338	82.676	0.236	5.894	43.698	87.396	0.229	0.022	0.048
3	44.122	88.245	0.211	5.284	46.152	92.305	0.206	0.017	0.040
4	54.179	108.359	0.189	4.719	56.499	112.999	0.185	0.015	0.033
5	56.743	113.486	0.203	5.076	57.823	115.646	0.200	0.018	0.037
6	70.354	140.707	0.204	5.096	73.534	147.067	0.200	0.017	0.032
Mean	52.054	104.109	0.207	5.187	54.176	108.352	0.203	0.019	0.039
S.D.	10.779	21.558	0.016	0.392	11.083	22.166	0.015	0.003	0.006

	EASL .5 KN (%)	Load at 0.2% Yield (kN)	Stress at Break (MPa)	Young's Modulus (MPa)	Stress at 0.2% Yield (MPa)	EASL 2.5 KN (%)	Energy to Break Point (J)	Tensile Energy Absorption (N/mm)
1	-	0.065	4.894	57.951	1.624	-	8.183	12.686
2	-	0.096	5.734	60.003	2.390	-	8.883	13.772
3	-	0.087	5.161	49.938	2.175	-	8.348	12.943
4	-	0.073	4.619	41.880	1.832	-	9.087	14.089
5	-	0.080	5.001	47.062	1.994	-	10.089	15.642
6	-	0.078	4.994	41.973	1.960	-	12.957	20.089
Mean		0.080	5.067	49.801	1.996		9.591	14.870
S.D.		0.011	0.373	7.772	0.266		1.781	2.762

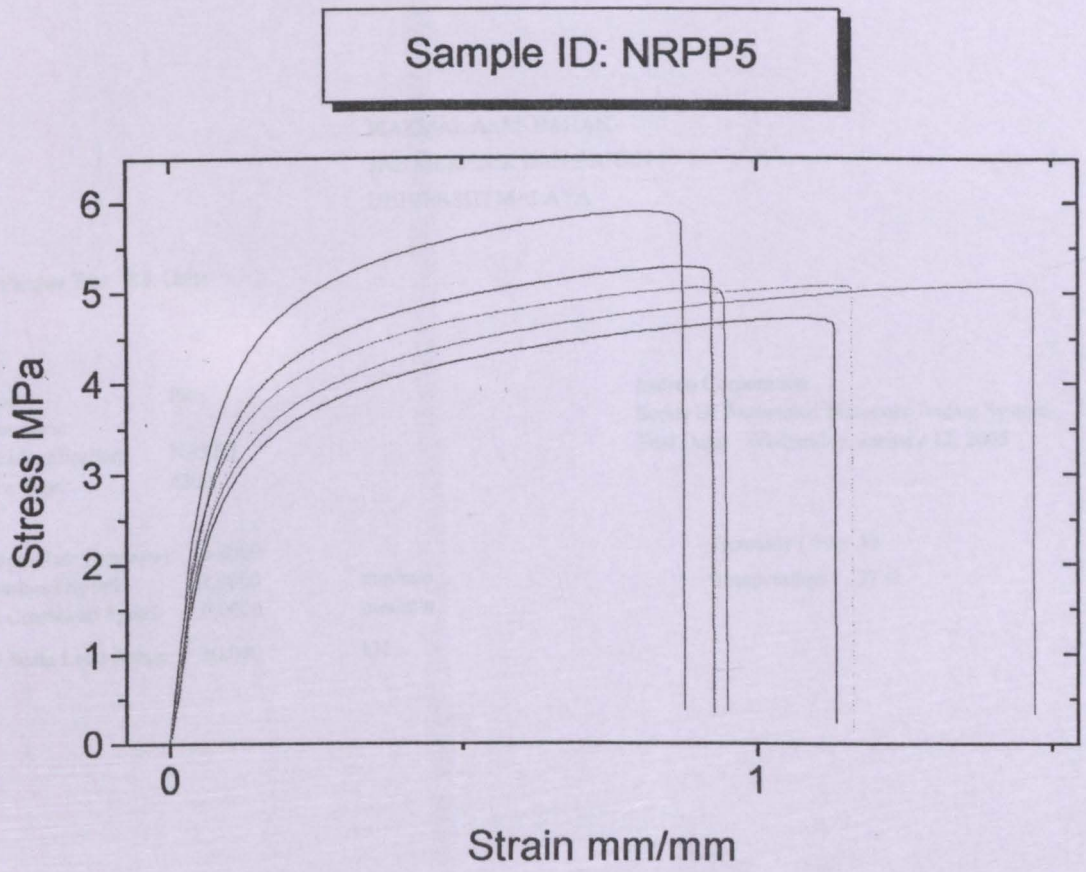

Figure B-5: Stress-Strain Diagram of Tensile Test Result of Batch 5

FLEXURAL TEST RESULTS:

Table B-6: Flexural Test Results of Batch 1

MAKMAL ASAS BAHAN
JAB.MEKANIK DAN BAHAN
UNIVERSITI MALAYA

3 Point Flexure Test - S.I. Units

Test type: Flex
Operator name:
Sample Identification: NRPP1
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Wednesday, January 12, 2005

Sample Rate (pts/secs): 0.8000
Crosshead Speed: 2.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 50.000 kN

Humidity (%): 50
Temperature: 27 C

Sample comments:

	Displcment at Yield (Max Load) (mm)	Strain at Yield (Max Load) (mm/mm)	Load at Yield (Max Load) (kN)	Stress at Yield (Max Load) (MPa)	Modulus (AutYoung) (MPa)
1	19.990	0.288	0.276	44.311	552.982
2	18.820	0.271	0.264	42.372	575.982
3	18.650	0.269	0.259	41.522	575.102
4	19.820	0.285	0.254	40.657	559.991
5	18.910	0.272	0.256	41.090	564.400
6	18.650	0.269	0.256	41.090	577.276
Mean	19.140	0.276	0.261	41.840	567.622
S.D.	0.603	0.009	0.008	1.343	10.020

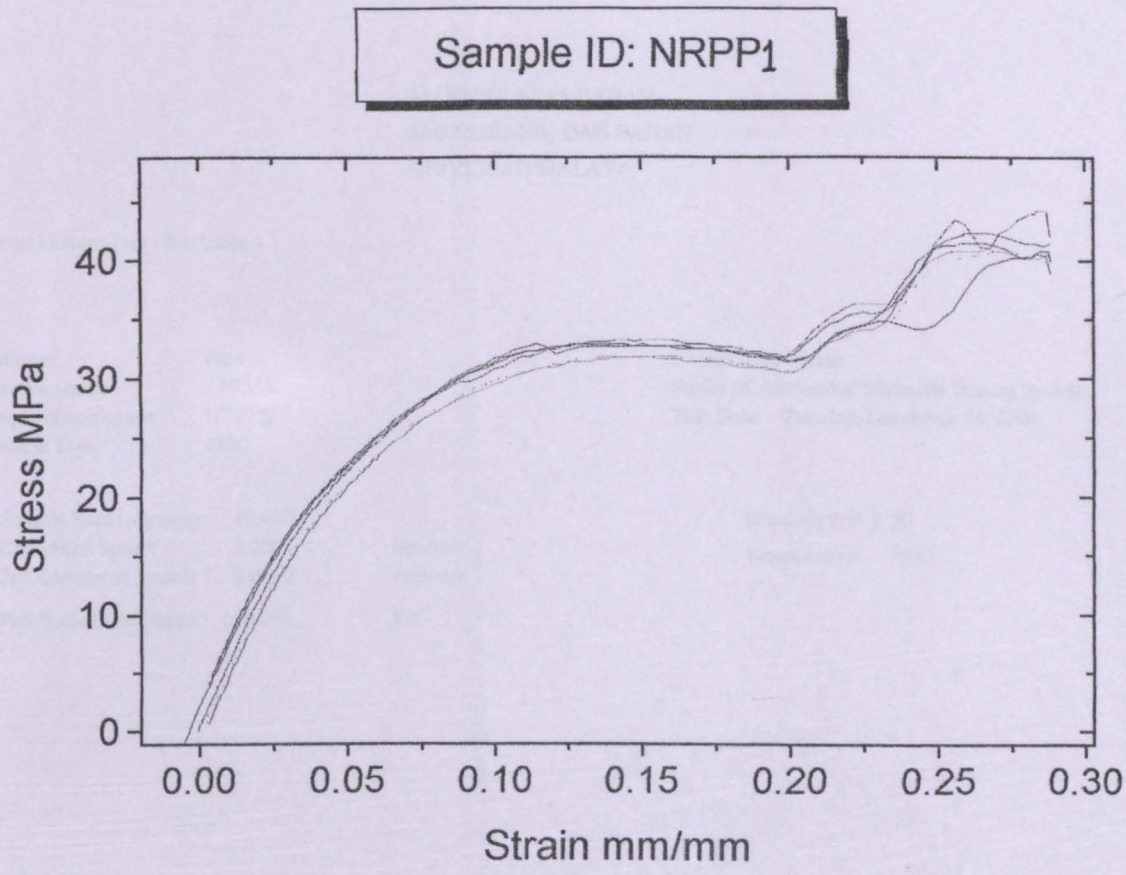

Figure B-6: Stress-Strain Diagram of Flexural Test Result of Batch 1

Table B-7: Flexural Test Results of Batch 2

MAKMAL ASAS BAHAN
JAB.MEKANIK DAN BAHAN
UNIVERSITI MALAYA

3 Point Flexure Test - S.I. Units

Test type: Flex
Operator name: ANUAR
Sample Identification: NRPP2
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Tuesday, December 14, 2004

Sample Rate (pts/secs): 10.0000
Crosshead Speed: 2.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 50.000 kN

Humidity (%): 50
Temperature: 73 C

Sample comments:

	Displcment at Yield (Max Load) (mm)	Strain at Yield (Max Load) (mm/mm)	Load at Yield (Max Load) (kN)	Stress at Yield (Max Load) (MPa)	Modulus (AutYoung) (MPa)
1	21.740	0.303	0.209	34.095	504.386
2	22.770	0.318	0.209	34.095	455.867
3	27.520	0.384	0.211	34.306	456.010
4	26.090	0.364	0.209	34.095	532.589
5	25.290	0.353	0.211	34.306	535.977
6	25.270	0.353	0.211	34.306	546.072
Mean	24.780	0.346	0.210	34.200	505.150
S.D.	2.145	0.030	0.001	0.116	40.551

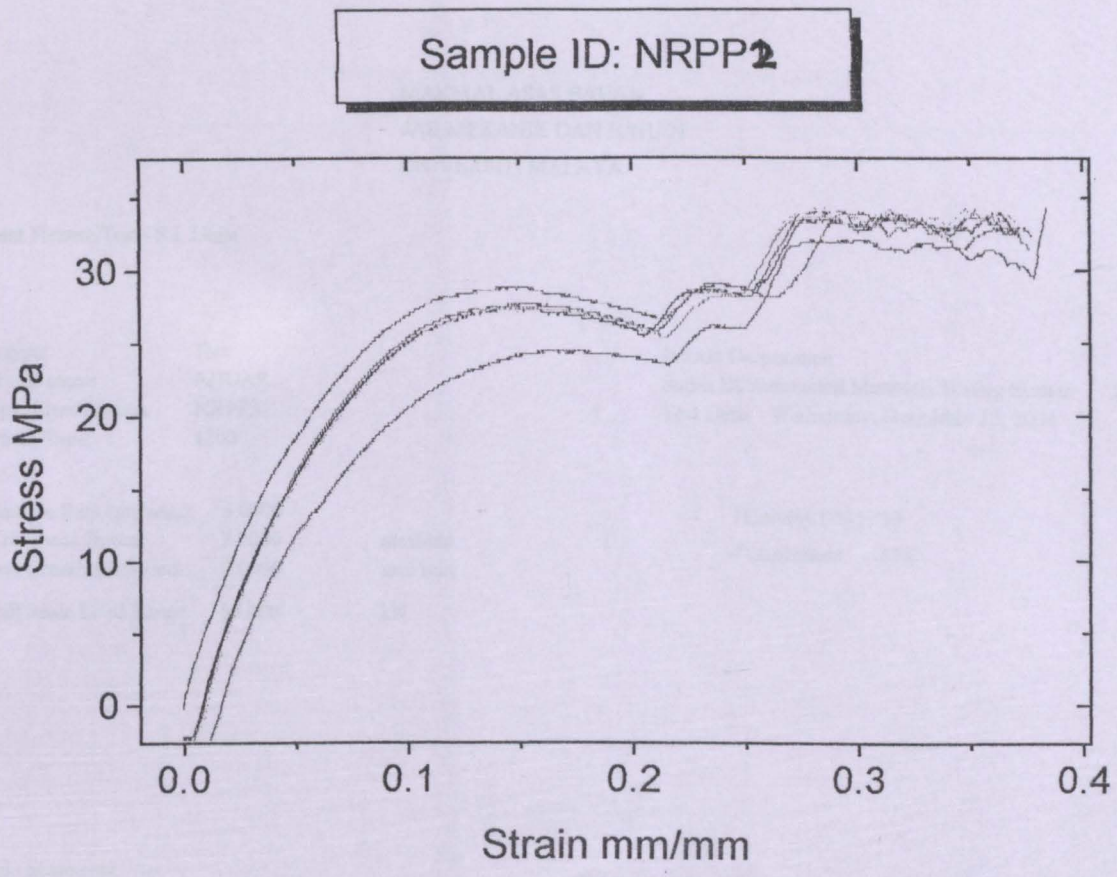

Figure B-7: Stress-Strain Diagram of Flexural Test Result of Batch 2

Table B-8: Flexural Test Results of Batch 3

MAKMAL ASAS BAHAN
JAB.MEKANIK DAN BAHAN
UNIVERSITI MALAYA

3 Point Flexure Test - S.I. Units

Test type: Flex
Operator name: ANUAR
Sample Identification: NRPP3
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Wednesday, December 15, 2004

Sample Rate (pts/secs): 5.0000
Crosshead Speed: 2.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 50.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Yield (Max Load) (mm)	Strain at Yield (Max Load) (mm/mm)	Load at Yield (Max Load) (kN)	Stress at Yield (Max Load) (MPa)	Modulus (AutYoung) (MPa)
1	11.800	0.165	0.099	16.173	318.365
2	9.970	0.139	0.098	15.955	353.739
3	9.580	0.134	0.106	17.259	418.734
4	11.540	0.161	0.095	15.518	341.967
5	11.770	0.164	0.094	15.299	369.284
6	10.290	0.144	0.101	16.396	386.337
Mean	10.825	0.151	0.099	16.100	364.738
S.D.	0.992	0.014	0.004	0.698	35.193

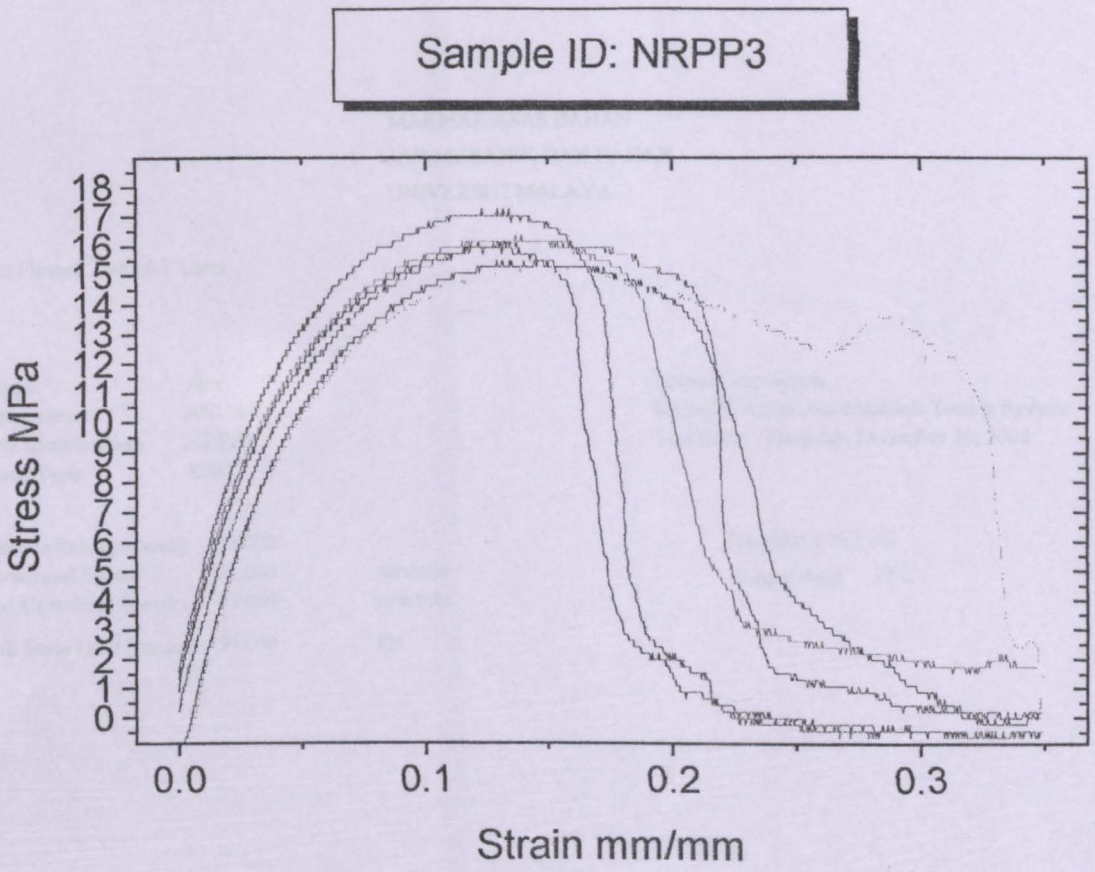

Figure B-8: Stress-Strain Diagram of Flexural Test Result of Batch 3

Table B-9: Flexural Test Results of Batch 4

MAKMAL ASAS BAHAN
JAB.MEKANIK DAN BAHAN
UNIVERSITI MALAYA

3 Point Flexure Test - S.I. Units

Test type: Flex
Operator name: ANUAR
Sample Identification: NRPP4
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Thursday, December 16, 2004

Sample Rate (pts/secs): 5.0000
Crosshead Speed: 2.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 50.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Yield (Max Load) (mm)	Strain at Yield (Max Load) (mm/mm)	Load at Yield (Max Load) (kN)	Stress at Yield (Max Load) (MPa)	Modulus (AutYoung) (MPa)
1	22.040	0.307	0.052	8.524	212.233
2	22.050	0.308	0.044	7.213	163.319
3	22.110	0.308	0.046	7.431	162.041
4	22.040	0.307	0.048	7.869	168.009
5	22.260	0.311	0.050	8.087	169.148
6	17.860	0.249	0.047	7.649	173.240
Mean	21.393	0.298	0.048	7.796	174.665
S.D.	1.733	0.024	0.003	0.472	18.848

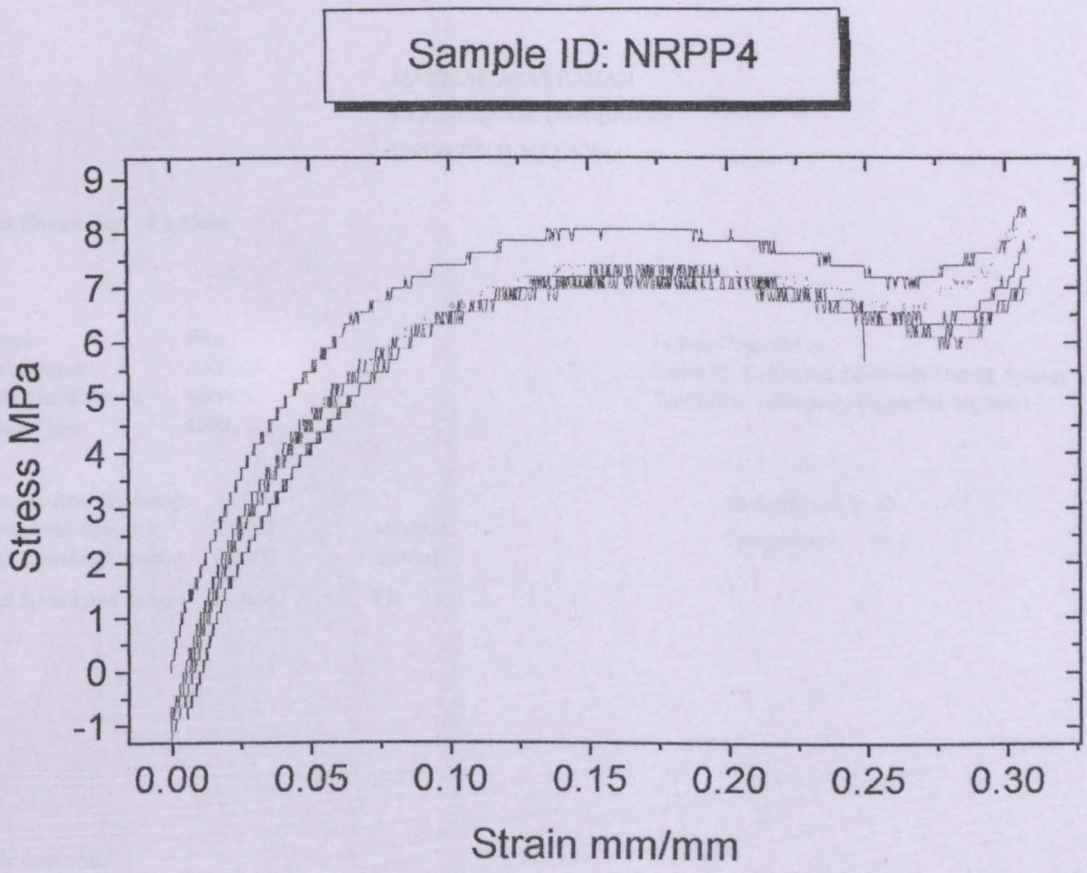

Figure B-9: Stress-Strain Diagram of Flexural Test Result of Batch 4

Table B-10: Flexural Test Results of Batch 5

MAKMAL ASAS BAHAN
JAB.MEKANIK DAN BAHAN
UNIVERSITI MALAYA

3 Point Flexure Test - S.I. Units

Test type: Flex
Operator name: ANUAR
Sample Identification: NRPP5
Interface Type: 4200

Instron Corporation
Series IX Automated Materials Testing System 7.51.00
Test Date: Thursday, December 16, 2004

Sample Rate (pts/secs): 5.0000
Crosshead Speed: 2.0000 mm/min
2nd Crosshead Speed: 0.0000 mm/min
Full Scale Load Range: 50.000 kN

Humidity (%): 50
Temperature: 23 C

Sample comments:

	Displcment at Yield (Max Load) (mm)	Strain at Yield (Max Load) (mm/mm)	Load at Yield (Max Load) (kN)	Stress at Yield (Max Load) (MPa)	Modulus (AutYoung) (MPa)
1	12.500	0.174	0.024	3.935	62.895
2	11.020	0.154	0.023	3.716	70.026
3	12.740	0.178	0.016	2.623	47.530
4	12.980	0.181	0.036	5.902	142.275
5	17.310	0.241	0.028	4.590	112.060
6	20.130	0.281	0.035	5.682	123.478
Mean	14.447	0.202	0.027	4.408	93.044
S.D.	3.496	0.049	0.008	1.247	38.005

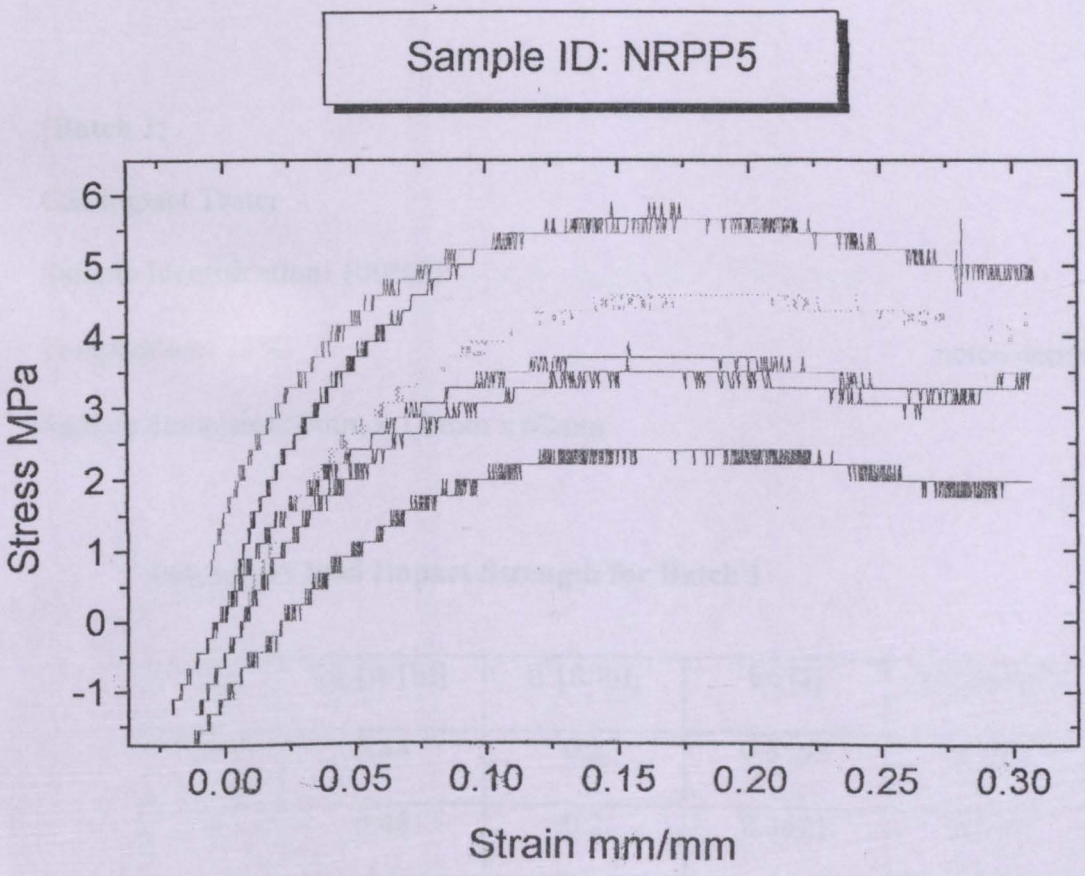

Figure B-10: Stress-Strain Diagram of Flexural Test Result of Batch 5

APPENDIX C

IZOD IMPACT TEST

[Batch 1]

CSI Impact Tester

Sample Identification: 100%PP

Temperature: 23°C notch depth: 2mm

Sample dimension: 6mm x 12 mm x 62mm

Table C-1: Izod Impact Strength for Batch 1

No	Er [ft.1bf]	E^0[ft.lbf]	Ec [J]	Is [KJ/m^2]
1	0.44	0.2	0.3253	6.378
2	0.46	0.2	0.3525	6.911
3	0.44	0.2	0.3253	6.378
4	0.46	0.2	0.3525	6.911
5	0.46	0.2	0.3525	6.911
6	0.46	0.2	0.3525	6.911
			Average	**6.733**

* All specimens are breakable.

[Batch 2]

CSI Impact Tester

Sample Identification: 80%PP, 20%NR, 0.5%DCP, 3%HVA-2

Temperature: 23°C notch depth: 2mm

Sample dimension: 6mm x 12 mm x 62mm

Table C-2: Izod Impact Strength for Batch 2

No	Er [ft.1bf]	E^0[ft.lbf]	Ec [J]	Is [KJ/m^2]
1	0.48	0.2	0.3796	7.443
2	0.48	0.2	0.3796	7.443
3	0.47	0.2	0.3661	7.178
4	0.50	0.2	0.4067	7.974
5	0.48	0.2	0.3796	7.443
6	0.47	0.2	0.3661	7.178
			Average	**7.443**

* All specimens are breakable.

[Batch 3]

CSI Impact Tester

Sample Identification: 70%PP, 30%NR, 0.5%DCP, 3%HVA-2

Temperature: 23°C notch depth: 2mm

Sample dimension: 6mm x 12 mm x 62mm

Table C-3: Izod Impact Strength for Batch 3

No	Er [ft.1bf]	E^0[ft.lbf]	Ec [J]	Is [KJ/m^2]
1	0.56	0.2	0.4881	9.570
2	0.54	0.2	0.4609	9.037
3	0.53	0.2	0.4474	8.772
4	0.51	0.2	0.4203	8.241
5	0.54	0.2	0.4609	9.037
6	0.53	0.2	0.4474	8.772
			Average	**8.904**

* All specimens are breakable.

[Batch 4]

CSI Impact Tester

Sample Identification: 50%PP, 50%NR, 0.5%DCP, 3%HVA-2

Temperature: 23°C notch depth: 2mm

Sample dimension: 6mm x 12 mm x 62mm

Table C-4: Izod Impact Strength for Batch 4

No	Er [ft.1bf]	E^0[ft.lbf]	Ec [J]	Is [KJ/m^2]
1	0.72	0.2	0.7050	13.823
2	0.74	0.2	0.7321	14.354
3	0.74	0.2	0.7321	14.354
4	0.70	0.2	0.6779	13.292
5	0.72	0.2	0.7050	13.823
6	0.73	0.2	0.7185	14.088
			Average	**13.955**

* All specimens are breakable.

[Batch 5]

CSI Impact Tester

Sample Identification: 30%PP, 70% NR, 0.5%DCP, 3%HVA-2

Temperature: 23°C notch depth: 2mm

Sample dimension: 6mm x 12 mm x 62mm

Table C-5: Izod Impact Strength for Batch 5

No	Er [ft.1bf]	E^0[ft.lbf]	Ec [J]	Is [KJ/m^2]
1	0.84	0.2	0.8677	17.013
2	0.86	0.2	0.8948	17.545
3	0.86	0.2	0.8948	17.545
4	0.88	0.2	0.9219	18.076
5	0.86	0.2	0.8948	17.545
6	0.84	0.2	0.8677	17.013
			Average	**17.456**

* All specimens are breakable.